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International Symposium

On The Ecological Effects of Arctic Airborne Contaminants

Hotel Saga • Reykjavik, Iceland
October 4-8, 1993

ABSTRACTS

S.J. Christie and J. Martin, Editors
J.E. Mello, Administrative Associate

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ABSTRACTS

S.J. Christie and J. Martin, Editor
J.E. Mello, Administrative Associate

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This volume contains abstracts submitted to the Symposium and accepted prior to July 1, 1993. Due to difficult financial situations in many countries, some abstract authors were unable to attend the Symposium. The Steering Committee has decided to publish all accepted abstracts in a gesture to improve communications and awareness among all arctic researchers.

Symposium participants should check the updated materials distributed at the Symposium to determine which of the abstracts in this volume will be presented as *platform talks or posters.*

This book is organized by session. Each session's abstracts are presented alphabetically by first author. The index in the back lists all authors and identifies the pages on which each author's abstracts are printed.

Left to right - Back row: Dr. Jüri Martin, Estonian Academy of Science (Estonia); Dr. Reginald Noble, Bowling Green State University (USA); Dr. Eiliv Steinnes, The University of Trondheim (Norway); Dr. Glen Shaw, Geophysical Institute-University of Alaska (USA); Dr. Dixon Landers, U.S. Environmental Protection Agency (USA); Dr. Gunnar Steinn Jonsson, Office of Environmental Protection (Iceland); ***front row*** : Dr. Per Larsson Institute of Limnology-University of Lund (Sweden); Dr. Jesse Ford, Oregon State University (USA).

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REGISTRATION AT THE SYMPOSIUM

1. The Registration/Information Desk opens at 10:00 A.M. on Sunday, October 3, 1993. During the Symposium, the Registration/Information Desk will be open daily from 7:00 A.M. to 6:00 P.M., except on Wednesday, during the excursion.

2. All participants must be registered.

3. Accompanying persons who wish to participate in the banquet or excursion may register for the specific activity at a reduced rate at the Registration/Information Desk.

4. All participants must check in at the Symposium registration desk to receive their registration packet, containing an abstract booklet, a name badge, writing materials, and the final Symposium schedule.

5. Authors should deliver their manuscripts to the editorial staff after they check in at the Registration/Information Desk.

6. The Registration/Information Desk will function as the communication center for the Symposium. Please use the message board located in the small lobby near the Registration/Information Desk to leave messages for other participants.

7. Sign-up sheets will be provided for reserving small meeting rooms, personal computers, and other services. A photocopy service will be available for a nominal charge.

8. If you have questions during the Symposium you may want to ask a member of the Staff, Steering Committee, or Session Organizers. You can identify these individuals by the color of the ribbons attached to their name badges:

   White ribbons — Staff
   Red ribbons — Steering Committee and Session Organizers

9. Members of the press and media attending the Symposium will have green ribbons attached to their name badges. Interviews can be arranged by the staff at the Registration/Information Desk.

PUBLICATION REQUIREMENTS

1. Both oral and poster presentations will be eligible for consideration as peer-reviewed publications in a special issue of *The Science of the Total Environment* (STOTEN). This special issue will be restricted to presentations made at the Symposium.

2. To be eligible for publication, all manuscripts must be delivered, in English, to the editor at the Symposium, and must be ready for peer review.

3. Manuscript preparation guidelines for STOTEN will be available at the Registration/Information Desk.

4. If you need to revise your manuscript as a result of interactions at the Symposium, contact the editorial staff to arrange access to the Editor's computers.

5. All manuscripts will receive two peer reviews and only those passing peer review will be published. The peer review process will begin immediately upon receipt of the manuscript, and may be completed at the Symposium.

6. Participants may be asked to review one or more manuscripts.

PRESENTATION INFORMATION

General Information

1. All presentations will be in English.

2. In general, presenters will have copies of their presentations for dissemination. However, some participants may not have been able to produce enough copies of their papers to meet demand at the Symposium. A photocopy service will be available for a nominal charge at the Registration/Information Desk.

Oral Presentations

1. All oral presentations will be timed. When the allocated time has elapsed, a timing device will inform the speaker, who then is expected to stop.

   a. Introductory speakers will have 30 minutes for their presentations. A 30-minute question and answer period will follow the three introductory presentations.

   b. Invited speakers in each session will have 30 minutes for their presentations, including questions and answers.

   c. Authors of contributed platform presentations will have 20 minutes for their presentations, including questions and answers.

2. Both an overhead projector and a 35-mm slide projector with remote controller will be provided for oral presentations. Carousel trays and returnable cardboard frames for mounting transparencies for overhead projection will be available at the Registration/Information Desk.

3. A speaker preparation room will be available for presenters to use while preparing their oral presentations. This room is equipped with a 35-mm projector, carousel trays, an overhead projector, a projection screen, and a clock.

Poster Presentations

1. Posters will be available for viewing throughout the Symposium, from 8:00 A.M. on Monday, October 4, 1993, until 5:00 P.M. on Friday, October 8, 1993.

2. Each poster has been numbered and will be displayed on a correspondingly numbered display panel in the poster presentation room, Hlidarsalur. A numbered listing of poster presentations and a map of the poster display area showing the location of each numbered poster panel are included in your registration packet.

3. To further assist you in locating related posters, the display panels have been color-coded to indicate the session to which each poster has been assigned. Your registration packed also includes a listing of posters in each session.

4. Formal poster presentation sessions are scheduled for early afternoon on Tuesday, October 5, and Thursday, October 7, 1993. Presenters of posters in Poster Session I will be present to discuss their posters during the Tuesday afternoon poster session. Presenters of posters in Poster Session II will be present to discuss their posters during the Thursday afternoon poster session. Presenters are not required to attend their posters at other times. However, poster presenters are encouraged to be available during breaks in oral sessions and immediately following the adjournment of each oral session.

   Poster Session I focuses on color-coded posters in the following sessions:

   Blue Panels: Session A: Pathways of Contaminants to the Arctic Biosphere
   Green Panels: Session B: Distribution of Contaminants in the Arctic Biosphere
   Yellow Panels: Session C: Human Health Issues

   Poster Session II focuses on color-coded posters in the following sessions:

   Red Panels: Session D: Arctic Ecosystem Responses to Atmospheric Contaminants
   Orange Panels: Session E: Contaminant Relationship to Climate Change
   Black Panels: Session F: Information Gaps and Research Needs

5. If you wish to arrange a meeting to discuss a poster with the presenter, leave a message on the message board, located near the Registration/Communication Desk.

The

International Symposium on the Ecological Effects of Arctic Airborne Contaminants

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"INTERNATIONAL SYMPOSIUM ON THE ECOLOGICAL EFFECTS OF ARCTIC AIRBORNE CONTAMINANTS"

Oct. 4, 1993 MONDAY	Oct. 5, 1993 TUESDAY	Oct. 6, 1993 WEDNESDAY	Oct. 7, 1993 THURSDAY	Oct. 8, 1993 FRIDAY
8:30 - 12:00 ***INTRODUCTORY SESSION*** I. Gunter Weller II. David Lean III. Kirill Kondratyev	***8:30 - 12:00*** SESSION "B" ***"Distribution"*** *Organizers:* *Per Larrson(chief)* *Derek Muir* *Eiliv Steinnes*	***DEPART at 9:00*** **"GOLDEN CIRCLE"** **EXCURSION** ***RETURN AT 6:00 p.m.***	***8:30 - 12:00*** SESSION "D" Part I ***"Ecosystem Response"*** *Organizers:* *Jesse Ford (chief)* *Juri Martin* *Reginald Noble* CHAIR: FORD	***8:30 - 11:50*** SESSION "E" ***"Contaminants & Climate Change"*** *Organizer:* *Glen Shaw*
LUNCH	LUNCH		LUNCH	LUNCH
1:30 - 5:20 SESSION "A" ***"Pathways"*** *Organizer:* Len Barrie CHAIR:	**1:30 - 3:30** *** POSTER SESSION I**		**1:30 - 3:30** *** POSTER SESSION II**	**1:30 - 3:30** SESSION "F" ***"GAPS/NEEDS"*** *Organizer:* *Dixon Landers* CHAIR: LANDERS
5:30 - 7:00 ***SOCIAL*** (refreshments/ chamber music)	***3:30 - 6:20*** SESSION "C" ***"Human Health"*** *Organizer:* *Gunnar Lundqvist*	**BANQUET 8:00pm** (Indigenous entertainment Indigenous banquet speaker Icelandic band)	***3:30 - 6:50*** SESSION "D" Part II ***"Ecosystem Response"***	**3:30** CLOSING COMMENTS ***5:00 - 7:00 - RECEPTION***

* *All posters available for viewing through entire symposium*

** *Buffet lunch available at hotel. Purchase tickets at registration desk ($ 23.00 USD/day)*

7/30/93

INTRODUCTORY SESSION

Organizer: Dixon H. Landers, Glen Shaw, and Juri Martin

The Introductory Session of the Symposium will feature several presentations concerning the association between Arctic Science and Policy as well as three invited scientific presentations to help define the context for the entire Symposium. The policy perspectives will be presented by government authorities from several Arctic countries. At this time, however, we are still confirming these talks. A final agenda will be available at the Registration Desk. The three introductory talks will be presented by:

Professor Gunter Weller, University of Alaska, Fairbanks, Alaska, USA;
Dr. David R. S. Lean, Water Research Institute, Burlington, Ontario, Canada;
Professor Kirill Ya. Kondratyev, Research Center of Ecological Safety, Russian Academy of Sciences, St. Petersburg, Russia.

The scientific presentations will focus on the unique features of the Arctic that influence the distribution, assimilation and effects of contaminants and global change on arctic ecosystems.

GLOBAL POLLUTION AND ITS EFFECT ON THE CLIMATE OF THE ARCTIC

Gunter Weller, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska 99775-0800, USA.

This paper describes the effects of global pollution, primarily the greenhouse effect, on the climate of the Arctic. Climate models indicate an amplification of greenhouse warming in the Arctic, but there are still many uncertainties about the magnitude and timing of the expected changes. This paper will focus on these uncertainties by examining the observed changes in temperature, sea ice extent, snow cover, and the permafrost regime. External and internal climate-driving forces will then be examined, including solar influences, greenhouse gases, volcanic eruptions, and changes in ocean circulation. Although all the signals of change in the polar regions are consistent with the global greenhouse scenario, it cannot be stated unambiguously that the greenhouse effect has already been observed in the Arctic, despite the fact that climate models indicate it to be largest there.

INFLUENCE OF ARCTIC ECOSYSTEM STRUCTURE ON BIOCONCENTRATION OF ATMOSPHERICALLY DERIVED CONTAMINANTS

David R.S. Lean, National Water Research Institute, Box 5050, Burlington, Ontario L7R 4A6, Canada

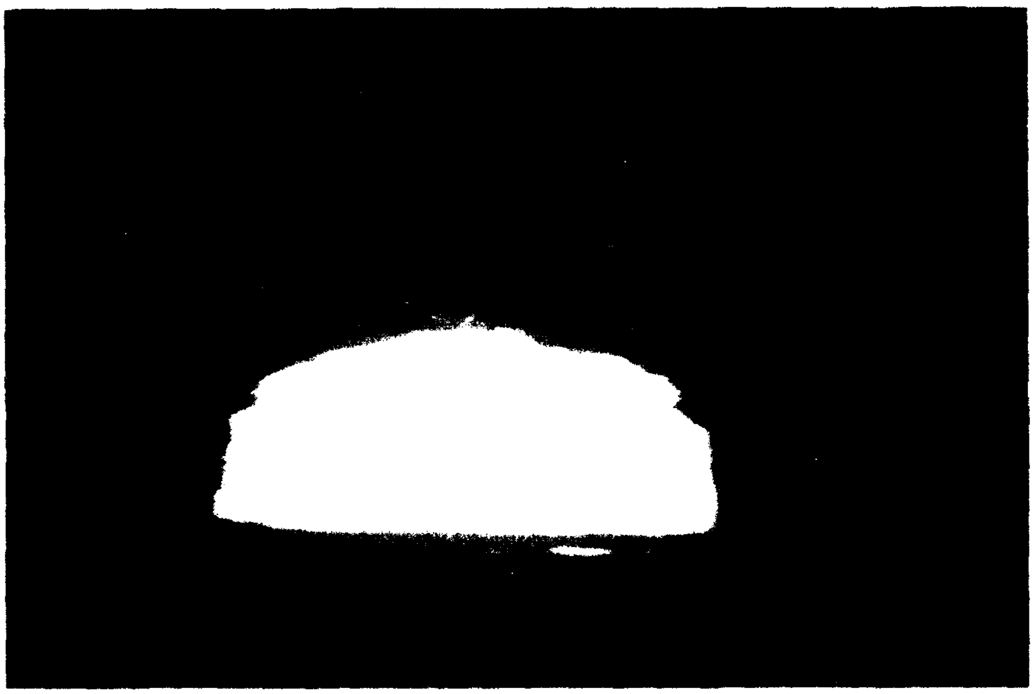
Approaches used to model contaminant bioconcentration in temperate regions are now being redesigned for arctic ecosystems. All have their particular merits and deserve attention. One group of models requires estimates or measurements of inputs and outputs and identification of flux rates between compartments thought to be important. While intellectually appealing and instructive in an accounting sense, such models cannot be used in a generalized way. They will not be sufficiently general to predict response, due to the complexity and the diverse ecosystems represented. Alternatively, other models rely on taxonomic information to construct pseudo food chain models complete with rate constants between organisms and their environment. Rarely is there sufficient information (or computer capacity) for such models to work. From studies in Ontario, we have observed that remote lakes receiving only atmospherically derived organochlorines and (possibly) mercury can have highly contaminated fish. The strongest driving variables are degree of planktivory and lipid content of the fish. Other information used recently is fish yield per unit primary production. Clearly, these variables are pushed to the extreme in arctic ecosystems and are totally foreign to conventional mass balance modelling. Attempts will be made to use the lessons learned from studies in temperate ecosystems and recommend approaches that might be useful for predicting contaminant accumulation by organisms in arctic ecosystems. Various scales of biological organization are necessary (ecosystem, population, individual, cellular, and biochemical). In addition, water renewal time and deposition rates must be important factors. The dilution effect of pristine water from glacier melt must also be considered. Rather than studying each contaminant separately, techniques that relate groups of contaminants may be useful in integrating the relative importance of plumes from alternative sources.

ARCTIC ATMOSPHERE POLLUTION AND CLIMATE

K.Y. Kondratyev, Research Center of Ecological Safety, Russian Academy of Sciences, 18 Korpusnaya Street, St. Petersburg 197042, Russia

Studies of climate forming processes in the Arctic have been conducted for some time. The principal features of these processes are determined by isolation of the ocean from the atmosphere by the ice cover and high sensitivity of the arctic climate to various external impacts, including atmospheric pollution. Of special interest is the phenomenon of arctic haze, which is caused by aerosols transported to high latitudes from industrial regions in Europe, Asia, and North America. Another kind of pollutant in the arctic atmosphere is chlorofluorocarbons, which reach the stratosphere and destroy the ozone layer. Finally, wet and dry deposition processes result in contamination of the surface in the Arctic by heavy metals and other toxic compounds.

Specific features of the arctic atmosphere are discussed. Emphasis is on two principal phenomena: (1) formation and development of arctic haze, and (2) heavy metals deposition in the Arctic. Investigations of pathways as well as physical properties of aerosols transported to the Arctic are reviewed in the context of a possible impact of arctic haze on climate. An intercomparison of heavy metals deposition in the Arctic and in other regions of the world is analyzed. The impact of ozone changes in high-latitude climate is briefly discussed. Based on comparison of the formation of "ozone holes" in the Antarctic and in the Arctic, it is shown that "microholes" may appear in the Arctic for rather short time periods because of the absence of stable circumpolar circulation in the atmosphere.



The sun seen through arctic air pollution. The strong temperature structure causes optical distortions of the sun's disk.

A. PATHWAYS OF CONTAMINANTS TO THE ARCTIC BIOSPHERE

Organizer: Len Barrie

Purpose: In this session, papers will be presented on processes that bring atmospheric contaminants into the arctic biosphere by precipitation and air-surface exchange mechanisms, as well as processes of transport and transformation in fresh and salt waters.

ORAL PRESENTATIONS

1:30 - 2:30	Len Barrie	Canada
2:00 - 2:30	Donald Mackay	Canada
2:30 - 3:00	Jozef Pacyna	Norway
3:00 - 3:20	Christophe Genthon	France
3:20 - 3:40	*Break*	
3:40 - 4:00	Michael Oehme	Norway
4:00 - 4:20	Sergey Chernyak	Russia
4:20 - 4:40	Renee Falconer	Canada
4:40 - 5:00	Dennis Gregor	Canada
5:00 - 5:20	Daniel Jaffee	USA

INVESTIGATION OF ATMOSPHERIC INDUSTRIAL POLLUTION IN THE ARCTIC REGIONS AND ESTIMATION OF AEROTECHNOGENIC ECOLOGICAL LOAD

Alexander Baklanov[1] and Daniel A. Jaffe[2]

[1] Institute of Northern Ecological Problems, Kola Science Center, Russian Academy of Sciences, 14 Fersman Street, Apatity, Murmansk Region 184200, Russia

[2] Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

Aerotechnogenic pollution of the environment in arctic regions is defined by local anthropogenic sources as well as by transfer of pollutants from the middle latitudes. Thus it is important to estimate the contributions of various sources of local, regional, and large-scale pollution in the Arctic. Results of atmospheric pollution monitoring at stations in the Kola North, including snow cover contamination, are presented. The mathematical models for investigating the effects of aerotechnogenic pollution of the environment in arctic regions on local, meso-, and regional scales are considered. The zones of aerotechnogenic load, with an excess of critical levels for northern ecosystems, are analyzed.

THE LYSIS OF NICKEL AND COPPER FROM THE SOIL CONTAMINATED BY METALLURGICAL DUST

Valery S. Barcan[1], R.P. Pankratova[2], A.V. Silina[2], and A.B. Koshurnickov[3]

[1] Lapland Biospheric Reserve, Kottulskogo G-77, Green Line 8, Monchegorsk 184280, Russia.

[2] Regional Laboratory of Arkhangelsk Forest Institute, Monchegorsk, Russia.

[3] Medical Statistic Centre, Monchegorsk, Russia.

We present the results of a long-term laboratory percolation experiment simulating the process of soil contamination by emissions from a nickel-copper smelter. Seventy-six lysimeter columns were composed of organic layer A_0 (mor) taken from illuvial humic ferriferrous forest podzol. Fine metallurgical dust containing nickel and copper was deposited on the surface of the substratum and columns were irrigated by sulfuric acid solutions with pH values of 3, 4, 5, and 6. This experiment, which was of 19 months duration, has shown that a rise in pH increases the degree of metal leaching from the soil, which provides a basis for supposing that the mobility of nickel and copper in the soil depends on the formation and movement of water soluble metallo-organic compounds and not on the acidity of precipitation. It is important to note the peculiarities of compounds deposited on the soil when studying the contamination of the soil by heavy metals. We calculate that 160–270 years is necessary for whole leaching of nickel from the organic layer, A_0, and 100–200 years for copper, depending on dust properties. The shorter period for copper is not explained by the greater inertness of nickel-containing phases of used dust. Since there is a strong barrier in the way of a downward migration of metals, namely illuvial horizons B + BC, the total duration of whole soil self-purification will amount to centuries.

PATHWAYS OF ARCTIC CONTAMINANTS: AN OVERVIEW

Len A. Barrie, Atmospheric Environment Service, 4905 Dufferin St., Downsview, Ontario M3H 5T4, Canada

The Arctic consists of a biologically active ocean surrounded by populated continents. The atmosphere is separated from the ocean by a crack-ridden leaky membrane of ice 1 to 6 m thick. The Arctic Ocean, sometimes known as the Mediterranean of the North, has a complex circulation. Topographically, the mountains of eastern Siberia, western North America, and the 3 km high plateau of Greenland are remarkable features that strongly influence atmospheric circulation and provide glaciers that trap valuable records of atmospheric deposition.

Chemicals reaching the Arctic by atmospheric and oceanic pathways have potential source regions whose sizes depend on the lifetime and mobility of the chemical in the environment. Thus short-lived substances such as acidic haze producing sulfates originate mostly from source regions in Eurasia closer to the Arctic than those that are highly persistent such as organochlorine pesticides, which potentially originate from any source on the globe.

There are several important classes of contaminants that are of concern, including chlorinated industrial organic compounds, organic pesticides, polycyclic aromatic hydrocarbons, metals, acids, and radionuclides. An overview of potential pathways of these into and throughout the Arctic is given, illustrated by a simple box model and recent observations of contaminant occurrence and trends that illustrate some of the processes influencing these pathways.

TOXAPHENE AND OTHER ORGANOCHLORINES IN AIR AND WATER AT RESOLUTE BAY, N.W.T.

Terry F. Bidleman[1], R.L. Falconer[1], and M.D. Walla[2]

[1] Atmospheric Environment Service, 4905 Dufferin St., Downsview, Ontario M3H 5T4, Canada.
[2] Department of Chemistry and Biochemistry, University of South Carolina, Columbia, South Carolina 29208, USA.

Very little is known about toxaphene (polychlorobornanes) in arctic air and water, relative to other organochlorine compounds. At Resolute Bay (75°N, 95°W) in August 1992, organochlorine compounds were collected from 3,000 m^3 of air using a glass fiber filter, followed by a polyurethane foam trap. Water samples (200 L) were passed through a glass fiber filter and a column of XAD-2 resin. Toxaphene and chlordane compounds were determined by capillary GC – negative ion mass spectrometry. Profiles of polychlorobornanes in air and water were skewed toward the lower molecular weight components of toxaphene, a pattern also seen in air and water from Lake Baikal, Siberia. The similarity in air and water fingerprints suggests gas-phase transfer of toxaphene from air to water. The octa- and nonachlorobornanes (sometimes designated T2 and T12) that are strongly accumulated in fish and marine mammals were present in air and water. Trans-chlordane was depleted relative to cis-chlordane in air samples, in agreement with other summertime arctic results. Other chlordane-related components identified were trans- and cis-nonachlor and heptachlor epoxide.

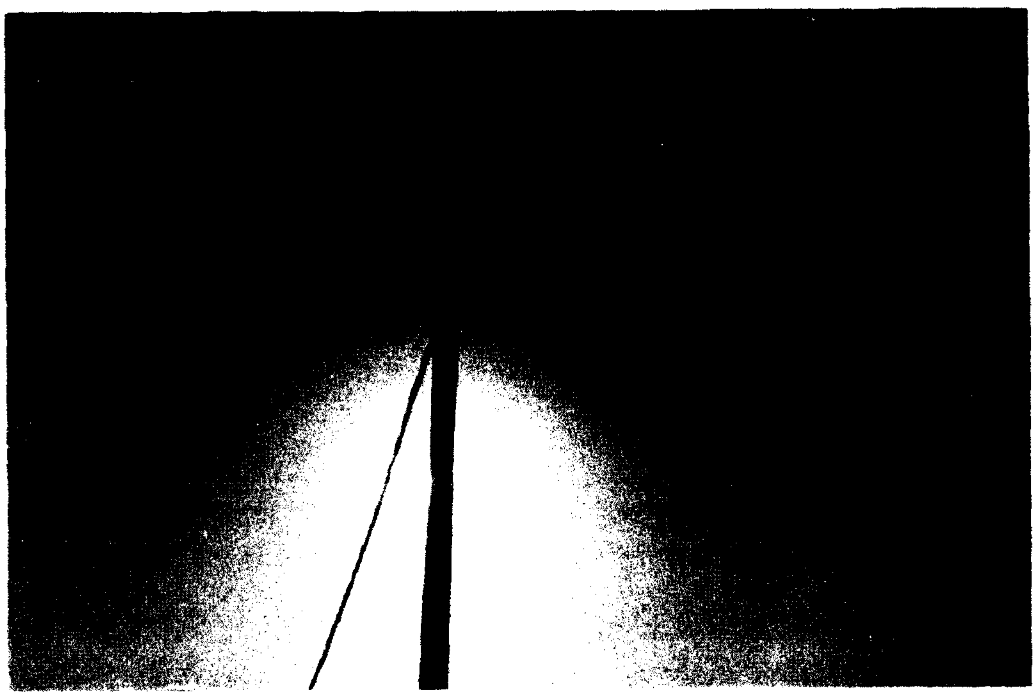
THE FREQUENCY OF HAZE EVENTS AT BARROW, ALASKA, 1983–1992

Howard A. Bridgman[1] and B.A. Bodhaine[2]

[1] Department of Geography, University of Newcastle, Callaghan NSW 2308, Australia.

[2] Climate Monitoring and Diagnostics Laboratory, NOAA, 325 Broadway, Boulder, Colorado, USA.

The first 120 days of the Barrow, Alaska, pollutant and meteorological record for the years 1983 to 1992 is reviewed to determine the frequency of arctic haze events and to find forecast signature features to identify a haze event. Pollutants considered include CO_2, aerosol scattering extinction (σ_{sp}), condensation nuclei (CN), CH_4, and aerosol black carbon (BC). Procedures followed include (1) establishing periods when clean air sector winds of greater speed than 3 m/s over at least 17 hours occurred, (2) correlating σ_{sp} against CO_2 to establish preliminary haze possibilities, and (3) removing periods when the wind direction varied more than 60°, the range of CO_2 was less than 1.5 ppm, and barotropic trajectories established a source region south of Barrow. Thirty-six periods were considered potential long-range haze transport events. Forecast signature features common to all events were not found. However, the following results emerged: (1) the majority of haze events (28 out of 36) occurred in January and March, with 1983 and 1986 having the largest number of events, (2) high correlations between σ_{sp} and CO_2 do not necessarily identify a haze event, but the relationship between CO_2 range and σ_{sp} maximum value could be important, (3) CN concentrations may represent either local sources or haze transport, without a clear distinction between, (4) haze at the surface is more likely to originate from the Arctic Basin pool of more polluted air created during late winter and early spring rather than from identifiable source regions, and (5) a haze event is more likely when all pollutants correlate strongly together.



Arctic haze scattering light around the sun. (The sun is blocked out by a telephone pole.)

FATE OF SOME CHLORINATED HYDROCARBONS IN ARCTIC AND FAR EASTERN ECOSYSTEMS IN THE RUSSIAN FEDERATION

Sergey M. Chernyak, Ministry for Natural Conservation and Natural Resources of the Russian Federation (c/o U.S. Department of Agriculture, ARS, NRI-ECL, Bldg. 007, Rm 223, Beltsville, MD, 20705, USA.

The impact of chlorinated hydrocarbons on the coastal environments of Russia has changed significantly since the mid-1980s. This appears to be due largely to several changes in use patterns over this period. Therefore, forecasts of the behavior of these chemicals in the far eastern and arctic marine areas, compared to the mid-1980s, require clarification.

As part of the Russian State Program, "Ecology of Russia," expeditions to the Barents and Japan Seas were organized in the spring and autumn of 1992. The purpose of these trips was to determine the ecological effects these pollutants may have on these regions.

This presentation will review results for a few widely dispersed chlorinated hydrocarbons in sea water, the surface microlayer, and bottom sediments. Results demonstrate that during the last five years, the composition of chlorinated hydrocarbons in far eastern seas has definitely changed towards an increase in the relative amounts of alpha-HCH and towards lower chlorinated PCB congeners. However, during the same period in the Arctic (Barents Sea), the composition and concentration of all the chlorinated hydrocarbons tended to agree with long-term forecasts, that is, no change in the relative abundance of HCH and PCB isomers.

The first results of our investigations of the ecological effects of arctic pollution, carried out as part of the AMAP program, will also be presented.

PHYSICAL AND METHODOLOGICAL PROBLEMS OF LONG-TERM FORECASTING OF THE ECOLOGICAL STATE OF THE CLIMATIC SYSTEM

Nikolay Doronin, M. Evseev, and G. Zablotsky, Institute of Arctic and Antarctic Research, 38 Bering Street, St. Petersburg, Russia

Long-term forecasting of the climatic system of the Earth and its ecological state is based mainly on mathematical modelling of the evolution of the atmosphere and the ocean. Analysis of the applicability of traditional hydro- and thermodynamic equations for description of planetary-scale processes reveals some strong restrictions in the approach. Returning to the basic principles of hydro- and thermodynamics, it becomes possible to derive modified equations, which take into account the limited speed of a disturbance propagation in a continuous media. The new equations simulate in more realistic ways the processes of contaminant redistribution in the atmosphere and the ocean. This opens up new opportunities in mathematical simulation of large-scale evolution. However, neither traditional nor modified equations can be successfully integrated over long time intervals due to the accumulation of errors introduced with the initial data. To avoid this, a new methodology for long-term forecasting is suggested. It is based on nonlinear thermodynamics and the theory of dynamical systems. The main result of the work is to present a reaction of a physical system to an external influence as a sum of stationary and nonstationary components. The decomposition is carried out using the observed data from the preceding time interval. The evolution of the components may be predicted with the help of the theory of dynamical systems for periods from months to decades.

ORGANOCHLORINE COMPOUNDS IN AIR SAMPLES FROM TWO SWEDISH LOCATIONS

Anna-Lena Egebäck, Ulla Wideqvist, L. Asplund, U. Järnberg, M. Strandell, and T. Alsberg, Institute of Applied Environmental Research, University of Stockholm, S-171 85 Solna, Sweden

Long-range transport by air of persistent organic compounds (e.g., PCB) and chlorinated pesticides has been demonstrated. To study the variability in air concentrations during different wind directions, air samples were collected at two meteorological stations. The places chosen were the southern point of Gotland, in the central Baltic, and Ammarnäs, situated in the north of Sweden, near the Swedish mountains and close to the Arctic Circle. Both were considered as background stations with little or no local discharges, although the southern one is more influenced by the industrialized areas of southern Sweden and the european continent. Sampling was carried out for 48 hours with a total sample volume of about 1500 m^3 using a high-volume sampler with glass fiber filter and polyurethane foam plugs. After trajectory analysis, samples collected during stable weather conditions were analyzed by GC-HRMS, mainly for PCB and pesticides, but non-ortho PCB and polychlorinated naphthalenes (PCN) will also be included. Concentrations of seven PCB congeners (CB28, -52, -101, -118, -138, -153, and -180) were in the low pg/m^3 range and varied within one order of magnitude among the samples. High concentrations were correlated with winds coming from the southwest and low concentrations with north to northwest winds. In one sample analyzed for non-ortho PCB, CB77, -126, and -169 were found in concentrations of about 1% of the concentrations of the seven congeners mentioned earlier, and they were bound to particles to a greater extent. On one sampling occasion, with the air masses coming from the north to both sampling sites, the concentrations of the seven PCB congeners were similar for both sites.

A POSSIBILITY OF SUPER LONG-RANGE FORECASTING OF THE TRANSPORT OF GENERAL AIRBORNE CONTAMINANTS IN THE ARCTIC

Mikhail Evseev, Institute of Arctic and Antarctic Research, 38 Bering Street, St. Petersburg, Russia

The calculation of contaminant transport by air fluxes requires long-term prediction of the air pressure field. A new oscillation model is suggested for super long-range prediction of the sign of mean monthly pressure pattern field anomalies in high latitudes of the earth. The calculation is based on long-range oscillations in the free atmosphere. The mean pressure pattern field anomalies are predicted by spectral GSM, which can obtain the information from outer processes. Forecasting for 10–15 years in advance may be made on the basis of daily 50 KPA heights for the 30–40 preceding years. The effectiveness of this approach was tested for the period 1949–1979. The results of super long-term forecasting may be used to predict arctic ecosystem dynamics and ice-cap evolution.

AIR-WATER GAS EXCHANGE AND EVIDENCE FOR METABOLISM OF HEXACHLORO-CYCLOHEXANES IN RESOLUTE BAY, N.W.T.

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Paired air and water samples were collected at Resolute Bay (74°N, 95°W) in August 1992 to estimate the gas exchange of hexachlorocyclohexanes (HCHs) and investigate possible loss processes in the water column. Average concentrations of α-HCH and γ-HCH in ocean surface water were 4.4 ± 0.9 and 0.37 ± 0.09 ng/L. These α-HCH and γ-HCH levels are about 60–100% and 45–65% of values reported for the central Arctic Ocean at Ice Island in 1986. Mean atmospheric concentrations of α-HCH and γ-HCH (132 ± 18 and 11 ± 1.3 pg m^{-3}) were 2–3 times lower than summer arctic levels in the 1980s. The ocean surface water (-1.4°C) was approximately in Henry's law equilibrium with respect to atmospheric HCH levels. Saturation values were 135% for α-HCH and 80% for γ-HCH, indicating a slight potential for volatilization and deposition of the two isomers, respectively.

The two α-HCH enantiomers in air and water were separated by chromatography on a γ-cyclodextrin capillary column. The enantiomeric ratio (ER = ratio of first/second eluting peaks) in air was 1.00 ± 0.05. This agrees excellently with a theoretical ER = 1.00 for unmetabolized α-HCH, and the ER = 0.98 ± 0.02 found for an α-HCH standard. The second-eluting enantiomer was depleted in water samples, resulting in ER = 1.14 ± 0.09 in Resolute Bay and 1.30 for one sample from Amituk Lake on Cornwallis Island. These results suggest that microbial degradation of HCHs is taking place in arctic lakes and near-shore marine waters.

PATHWAYS OF ATMOSPHERIC TRANSPORT TO THE HIGH LATITUDES: INVESTIGATIONS USING GENERAL CIRCULATION MODELS

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Atmospheric parameters that determine the large-scale distribution of atmospheric constituents include winds, turbulence, convection, and precipitation. These variables are tentatively simulated in general circulation models (GCMs) of the atmosphere. If tracer/climate interactions can be adequately formulated and implemented in GCMs, then the resulting models can be useful in investigating the pathways of large-scale transport of atmospheric species. Two coupled tracer/climate models have been set up on the bases of two different GCMs, and they are currently being used to study the distribution of a range of atmospheric tracers: desert dust, sea salt, ^{222}Rn, ^{210}Pb, and ^{7}Be. These tracers differ greatly, particularly with respect to their sources, which allow investigation of different and complementary aspects of the models. However, the tracers all have relatively short life times in the troposphere, of the order of a few days, typical of many reactive species and of most nonreactive aerosols. Previous work on the Antarctic region (Genthon, 1992) has revealed that climate features particular to the region, like the deep winter inversion, exert a strong control on the seasonal variability of dust, and possibly of other species, in the Antarctic surface atmosphere. We now turn to the high northern latitudes, to analyze if and how the models can capture the features of atmospheric composition in the north polar regions, where the pathways of transport are obviously an important issue.

Genthon, C. 1992. Simulations of dust and sea salt in Antarctica with a general circulation model of the atmosphere. *Tellus* 44B:371-389.

THE HISTORICAL RESIDUE TREND OF PCBs AND SELECTED ORGANOCHLORINE PESTICIDES IN THE AGASSIZ ICE CAP, ELLESMERE I., CANADA

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Lake sedimentary records generally provide only a crude time trend of contaminant deposition, especially in arctic lakes where sedimentation rates are low. Also, these data can be difficult to interpret, due to multiple process functions that can affect the trend. Current detailed measurements of contaminant deposition cannot provide a historical perspective except through long-term monitoring programs. In the Arctic, ice caps provide an alternative to lake sediments, in that the annual snow layers reflect the atmospheric deposition. As a result of the remoteness of the ice cap and the limited summer melt, annual layers undergo little chemical change, especially after the first summer season, and therefore provide a well-defined historical record. Initial work was undertaken at this site beginning in 1986, but a major effort was undertaken in 1993, during which samples covering 30 years were collected from a snow pit (80°49'50"N, 72°56'30"W). Large volume snow samples were obtained for determining PCB congeners and selected organochlorine pesticides. In addition, 5- to 10-year period samples were collected from the base of the snow pit using a corer to provide an extended record of deposition. The trend results will be discussed in light of previous data from the ice cap and from current contaminant deposition measurements.

DEPOSITION OF ATMOSPHERICALLY TRANSPORTED POLYCHLORINATED BIPHENYLS IN THE CANADIAN ARCTIC

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Since 1986, efforts have continued to quantify the deposition of trace organic contaminants, including PCBS, to the Canadian Arctic. The cold, dry air minimizes wet scavenging as we know it in temperate, more humid regions, but the stability of the air masses, and the long calm periods with ice crystal deposition interspersed with snowfalls, are likely to be effective scavenging mechanisms. Measurements of contaminants in snow, therefore, are good indications of the flux of PCBs to the Arctic. Beginning in the fall of 1990, large volume snow collectors were designed and installed at two High Arctic weather stations, Mould Bay (76°15'N, 119°16'W) and Eureka (80°00'N, 86°36'W). These collectors, each with a surface area of approximately 4.5 m^2, were intended to intercept ice crystals and falling snow during calm periods, but they also retain some quantity of windblown snow, due to the screening installed around their perimeters. Samples were collected once a week, weather conditions permitting. While fluctuations occur, there appears to be a general increase in concentration of the lighter congener groups (two, three, and four chlorines) toward the end of the winter season at Mould Bay, while concentration of heavier congeners tends to be variable. PCB concentrations (sum of the 51 congeners) throughout the sampling season ranged from approximately 8 ng L^{-1} to more than 20 ng L^{-1}. Deposition rates during the two years of measurement will be considered in light of annual snowpack samples and temporal trend data from the Agassiz Ice Cap.

TRANSPORT AND FATE OF CONTAMINANTS IN THE CHUKCHI SEA: PRELIMINARY MASS BALANCE OF HEXACHLOROCYCLOHEXANE (HCH)

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Organochlorine pesticides are among the atmospheric pollutants commonly detected in the Arctic. They are also widespread in ice, snow, and fresh water and in surface layers of coastal and marine waters. In the Chukchi Sea, there might be a strong flux of such pesticides with inflowing waters from the northern Bering Sea, the Bering Sea-Anadyr waters, and the Alaska coastal waters. Data on hexachlorocyclohexane (HCH), a highly toxic synthetic organochlorine compound whose gamma isomer is commonly known as lindane, have been used to exemplify the distribution and fate of environmentally persistent contaminants. It is estimated that the total flux of HCH into the Chukchi Sea, via the Bering Strait and from the atmosphere, is ca. 120 mt per year; about 10% of that amount is due to atmospheric flux. Under assumptions about the level of primary productivity and the carbon content of suspended particles, the HCH residence time in the water column is calculated to be 1.6 years. Only a small fraction of the total amount of HCH in the Chukchi Sea is incorporated into the biota, although its concentration in marine mammals may be fairly high. For example, beluga whale, an important subsistence species in Kotzebue Sound, may contain 20–50 mg of HCH per animal (0.1–0.3 mg/kg of blubber).

DEPOSITION OF SULFATE AND HEAVY METALS ON THE KOLA PENINSULA

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To accurately assess the local, regional, and global impacts of air pollution sources in the Arctic, we need information on the emissions, transport, and deposition of these pollutants. In 1991, University of Alaska Fairbanks and the Kola Science Center initiated a joint experiment to address these topics, including both modeling and field experiments. Some of the questions we address in this program are: (1) What are the source strengths for the important pollutant categories on the Kola Peninsula? (2) How extensive are the regions in which critical loads for S and/or heavy metals are exceeded? (3) What is the size distribution of the aerosols containing heavy metals and what fraction of the emissions are removed locally? (4) How do the transport patterns and atmospheric chemical processes change seasonally in the Arctic?

Snowpack samples were collected from 20 sites on the Kola Peninsula, Russia, during April 1991. In the vicinity of the Monchegorsk smelter, elevated concentrations of SO_4^{2-} and metals were observed in the snowpack. Based on the snowpack deposition and the estimated emissions, we calculate that less than 1% of the S and 30–50% of the metal emissions of the Monchegorsk smelter are removed to the snowpack within 20 km during winter. This suggests an important role for sedimentation of large particles containing metals near the smelter. This project was funded by Earthwatch and its research corps.

DIFFERENCES IN LEVELS AND PATTERNS OF CHLORINATED HYDROCARBONS ALONG A SOUTH-NORTH GRADIENT IN THE BALTIC SEA

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During one year, persistent pollutants were continuously determined in air and precipitation at 16 stations on islands and in coastal areas in the Baltic Sea to estimate the load. Pollutants in the lower atmosphere were sampled by filtering 1000 m^3 of air through polyurethane foam filters. Pollutants in precipitation were sampled by a stainless steel funnel (1 m^2) and collected on polyurethane foam filters. The stations cover a latitude from 54°N to 65°N. In total, 450 air samples and 220 rain samples were collected.

Pollutants detected in air include 70 PCB congeners, DDTs, pentachloroanisole, hexachlorobenzene, and a-, b- and g-hexachlorocyclohexane. The results show different levels of organochlorines related to location, with higher concentrations in the air samples from the south. Different patterns of organochlorines in the northern parts of the Baltic Sea compared to the southern parts were also recorded. Organochlorines with higher volatility (> 1 mPa), such as HCH and low chlorinated PCBs (dominion 1 27), dominated in the northern samples during autumn, spring, and winter. This was not the case for samples from the south, where the compounds with lower vapor pressure dominated in the spring, summer, and autumn samples. These differences will be discussed in relation to geographical and climatic factors.

AIRBORNE HEAVY METALS ON THE KOLA PENINSULA: AEROSOL SIZE DISTRIBUTION AND DEPOSITION

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Emissions from the Monchegorsk smelter are estimated to be 230,000, 1,800, and 2,700 metric tons per year of SO_2, Cu, and Ni, respectively. To understand the regional and arctic impacts of these emissions, it is necessary to develop a detailed understanding of the deposition processes. Recent work has indicated that a large fraction of the metal emissions are deposited locally. This suggests an important role for the sedimentation of larger particles containing metals. This study attempts to quantify the heavy metal composition and size distribution of the airborne aerosols, as well as dry deposition, by collection on teflon plates. Simultaneous SO_2 and SO_4^{2-} data can be used to derive oxidation rates in the smelter plume. Data from field campaigns conducted in the summers of 1992 and 1993 will be discussed.

TROPICAL AIR MASSES CONTAINING DUST, POLLEN, AND INSECTS IN THE CENTRAL ARCTIC

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During two periods of field work on the Franz-Joseph Land glaciers (June 19–21, 1959, and June 21, 1961), we observed a sharp warming (up to +14°C and +11°C, respectively), with strong southern winds, catastrophic melting, dust haze darkening, and remarkable dust deposition on the snow. Dust on the surface (up to 500 mg/m^2) contained plant pollen and spores in amounts of 300–800 mg/m^2. From 1132 pollen and spores, 91% belong to plants not existing on the archipelago. Most belong to boreal flora, though some, such as some wormwoods, have a more southern origin. Several continental flies (Syrphus, Phaonia) were also gathered. In both cases, the archipelago was between a deep low pressure area to the west and a high to the east. Air masses in the middle troposphere originated from the Caspian Sea area, which in the summer is often influenced by tropical air masses. The frequency of such situations is estimated and weather pattern types according to Dzerzievskyi are identified for each case. The rare though catastrophic tropical air mass invasions seem to be the most important mechanism of tropospheric aerosol input to the central Arctic. The relation of transportability to wind velocity is evidently nonlinear. Thus, in the Arctic, systematic air and surface dust sampling during tropical air mass invasions is critically important.

IDENTIFICATION OF THE POTENTIAL SOURCE LOCATIONS FOR ELEMENTS OBSERVED IN PARTICLES COLLECTED AT NY ÅLESUND

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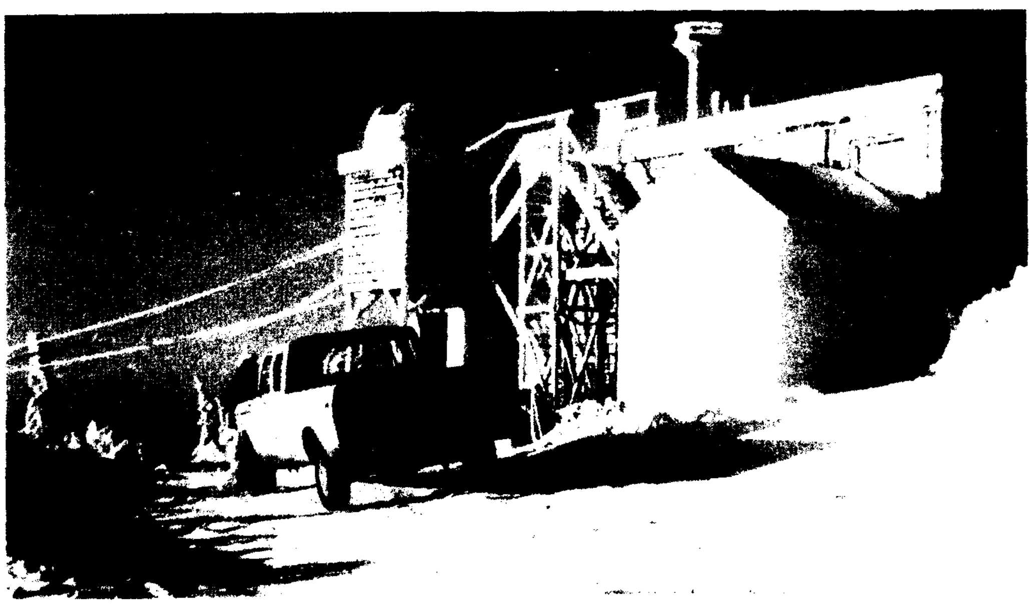
A receptor model that combines elemental composition data with meteorology in the form of air parcel back trajectories, potential source contribution function (PSCF), has been applied to airborne particle composition data from Ny Ålesund, Spitsbergen. The region around a receptor site is divided into a rectangular gridded array. In this case, the grid cells are 2.5° latitude by 2.5° longitude. The PSCF value is calculated using the number of back trajectory endpoints that fall into a given cell. The ratio of the number of endpoints that can be associated with an elevated concentration of a species of interest to the total number of endpoints falling into the cell associated with any of the samples is the conditional probability that the particular location is associated with the observed elevated concentration. Thus, a conditional probability map is developed that identifies the high potential locations of the sources of the species of interest.

In this study, a series of 109 daily samples obtained during the first half of 1989 were analyzed using neutron activation analysis and particle-induced x-ray emission to provide a suite of 44 elements. Trajectories have been calculated at the 850 mbar pressure level by Dr. J. Harris of NOAA. The series of PSCF conditional probability fields are plotted over maps of the region and can be compared with emission patterns. A selected set of these maps will be presented and discussed in terms of the likely source areas and what is known about emission rates.



Ester Dome Observatory, Alaska. Measurements of Arctic haze pollution have been carried out from this facility near Fairbanks for many years.

TRANSPORT OF CONTAMINANTS TO THE ARCTIC: PARTITIONING, PROCESSES, AND MODELS

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A review is presented of the processes by which organic contaminants are transported to the Arctic and become subject to deposition and absorption into terrestrial, aquatic, and marine ecosystems with subsequent transport and transformation within the abiotic and biotic media that comprise these ecosystems. The rates of these processes are controlled by the physical and chemical properties of the contaminants, notably vapor pressure, solubility in water, and various partition coefficients such as those to organic carbon, lipids, plant matter, and snow and ice surfaces. These properties are, in turn, profoundly affected by temperature, especially those involving air to condensed phase partitioning. It is suggested that the unexpectedly high concentrations of certain organo-chlorine chemicals observed in polar regions can be explained, at least in part, by the temperature dependence of these partitioning phenomena. It is concluded that (1) there is a need to measure and correlate these fundamental properties and partition coefficients over a relevant range of temperature, (2) the full implications of the effect of low temperatures on chemical fate can only become clear through the construction of models describing the multimedia partitioning, transport, and transformation of chemicals at these temperatures in representative ecosystems, and (3) there is a need to identify the characteristics of the class of chemicals that is susceptible to what has been termed "cold condensation" in polar regions.

ASSESSMENT OF THE EFFECTS OF GAS PRODUCTION ON ECOSYSTEMS IN THE NORTH OF WESTERN SIBERIA

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The natural gas production complex is characterized as a source of environmental pollution, emitting nitrogen and carbon oxides, methane, heavy metals, dust, ozone, etc. Nitrogen oxide emissions account for the greatest part of the pollution, spreading to a distance of up to 15 km from the source, at a concentration of 0.8–1.4 mg/m^3. Another serious pollutant is methane. The dynamics of the composition and quantity of emissions from the complex were analyzed at various stages of its construction and during various regimes of operation. This report discusses the direct and indirect effects of gas production on local ecosystems, taking into account the natural conditions of the north part of western Siberia. The gas production facilities present the main source of local emissions, while contributing to global atmospheric pollution as well. The area under study was zoned with the aim of proposing a monitoring system.

POLYCYCLIC AROMATIC HYDROCARBONS, DIOXINS, AND FURANS IN ALASKAN LAKE SEDIMENTS

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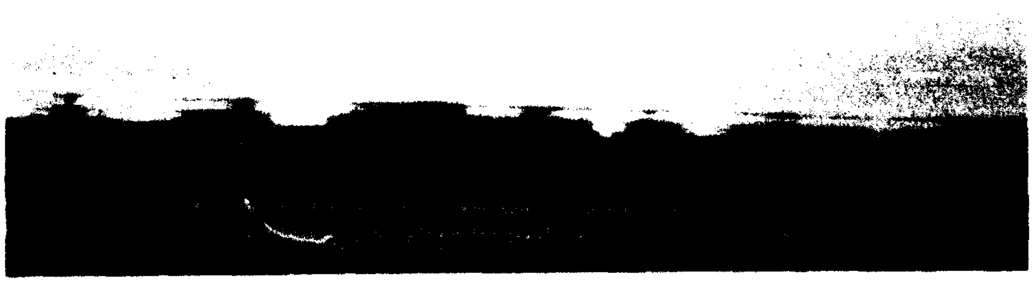
Sediment cores were collected from two Alaskan lakes, Wonder Lake and Lake Schrader, during April 1991 as part of the U.S. EPA's Arctic Contaminant Research Program. Both lakes are several kilometers long, with basins greater than 50 m in depth. Wonder lake, a subarctic lake, is located in Denali National Park and is surrounded by a coniferous forest within the Alaska Range. Lake Schrader is an arctic lake at the foothills of the Brooks Range and is located within the Arctic National Wildlife Refuge. Cores from these lakes were sectioned and dated by radiometric techniques. The sediments were then analyzed for 3–7 ring PAH and tetra-octa PCDD/F using GC/MS methods developed at EML. In general, the parental PAH and PCDD/F concentrations in Wonder Lake were from one to three orders of magnitude lower than concentrations found in surface sediments from the contiguous United States. Since the sedimentation rate in Wonder Lake is low, the flux of these contaminants is extremely low. Results of organic analyses of Lake Schrader sediments will be available shortly for comparison.



Mirages of the Alaska Range. The Arctic has some of the most spectacular mirages on the planet due to strong variations of temperature in the atmosphere.

COMPARISON OF 1982–1984 AND 1992 AMBIENT AIR CONCENTRATIONS OF PERSISTENT ORGANOCHLORINES AT SPITSBERGEN AND THE NORWEGIAN MAINLAND

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During 1982–1984, selected persistent organochlorines in ambient air were determined at Bear Island, Jan Mayen, Ny Aalesund/Spitsbergen, Jergul (northern Norway), Kårvatn (western Norway), and Birkenes (southern Norway). These measurements were repeated at the latter four stations in 1992. Jergul was replaced with Svanvik, which is close to the Russian border. In addition to the compounds determined during the first measuring period (α- and γ-hexachlorohexane, hexachlorobenzene, cis- and trans-chlordane, sum of penta-, hexa-, and heptachlorobiphenyls), cis- and trans-nonachlor were included in the 1992 campaign, as well as the congener specific analysis of the polychlorinated biphenyls (PCBs) 28, 31, 52, 101, 105, 118, 153, 156, and 180 (IUPAC numbering). The quantification method consisted of clean-up by different liquid chromatographic techniques followed by high-resolution gas chromatography combined with low-resolution negative ion chemical ionization mass spectrometry or high-resolution mass spectrometry at resolution 10,000. The quality assurance measures of the analysis method have been considerably improved, compared to the 1982–1984 measurements, and follow new international quality assurance criteria for ultra trace analysis. These criteria include determination of recovery rates for each single sample, a defined system of blank determinations, and part quantification by the isotope dilution technique. The concentration differences between 1982–1984 and 1992 will be discussed in detail, as well as the quality assurance requirements for such measurements. Furthermore, the reliability of the results obtained by high-resolution mass spectrometry and low-resolution negative ion mass spectrometry will be critically evaluated.

THE ORIGIN OF ARCTIC AIR POLLUTANTS: LESSONS LEARNED AND FUTURE RESEARCH

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Vertical profiles of air concentrations obtained during several measurement programs in the Arctic offer an explanation of the physical and chemical characteristics of arctic air pollution and its origin. In the lower level of the troposphere (up to 3 km), arctic haze, the phenomenon of large-scale industrial air pollution found all through the arctic air mass, is often strongly banded. The temperature and wind profiles measured through the haze layers suggest that their thermal stability is sufficient to maintain these laminar structures, despite differential advection of the layers by jets of wind. Aerosol size measurements in the lower and upper parts of the troposphere during winter show significant variations, with fine particles ($< 1.0\ \mu m$) dominating the lower part and coarser particles predominating in the upper part. The larger concentrations of small particles in the lower part of the troposphere seem to be associated with air masses transported directly from emission regions. They may also result from an enhanced gas-to-particle conversion. Vertical profiles of the summer arctic aerosol indicate that enhanced concentrations of particles are very seldom measured in the lower part of the troposphere. Particles in the upper part are similar in terms of size to the particles measured in the upper layer during winter.

Transport of air pollutants to the Arctic is governed by the general circulation of air masses in the region, which is different in winter and summer. Anticyclones play the dominant role in providing the proper conditions for this transport, which begins in areas where air is subsiding from upper levels (high pressure) and is flowing outward to converge in frontal regions near cyclones (low pressure) with subsequent ascent of air. In winter, air driven by the strong Siberian anticyclone flows mainly from the Eurasian continent into the Arctic and then out over the North American continent or into major cyclonic regions in the Aleutians and off southern Greenland. As a result, the emissions from anthropogenic sources in Eurasia, and particularly in northern Russia, dominate (at least two-thirds) the pollution measured in the Arctic during winter. The major emission regions include the Urals, the Kola Peninsula, and the Norilsk area. In summer, south-to-north transport from Eurasia is replaced by a weak north-to-south transport. Furthermore, flow into the Arctic from the north Atlantic (with pollutants emitted in Europe) and the north Pacific is more frequent. Accompanying this seasonal variation is a marked variation in cloud cover and precipitation, with less cloud and less precipitation in winter. Polluted air masses, carrying a mixture of anthropogenic and natural compounds from a variety of sources in different geographical areas have been identified in the arctic upper troposphere.

Although there has been significant progress in understanding the characteristics of arctic air pollution, several important aspects need further explanation. They can be grouped into at least three major research subjects: (1) What happens to air pollutants as they enter the Arctic? (2) What are the direct and indirect effects of arctic haze on the local ecosystem? (3) What are the global effects of arctic air pollution? These questions are discussed in the paper.

THE RECENT HISTORICAL TREND IN THE DEPOSITION OF POLYCYCLIC AROMATIC HYDROCARBONS AND ELEMENTAL CARBON TO THE AGASSIZ ICE CAP, ELLESMERE ISLAND, NWT, CANADA

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Lake sedimentary records of contaminants can be used as indicators of fluxes of contaminants to the environment. However, the data often exhibit poor resolution for short time scales and can also represent multiple source processes. Alternatively, polar ice caps provide annual accumulation records for atmospheric deposition only. Owing to the prevalent conditions, deposited snow and ice layers undergo little chemical change and are temporally well defined. Field work was undertaken in early 1993 to further investigate the potential of polar ice caps for the use of determining recent historical records of the atmospheric deposition of contaminants in the Arctic. Discrete annual snow and ice layers were taken from a large snow pit excavated on the Agassiz Ice Cap (80°49'50"N, 72°56'30"W), Ellesmere Island. Large volume samples were obtained for the determination of polycyclic aromatic hydrocarbons (PAHs) and elemental carbon (EC), both of which can be used as indicators of anthropogenic environmental contamination. Samples extending back for a period of 30 years were obtained. In addition to these annual samples, 5- to 10-year composite ice cores were also retrieved from deeper layers, extending the record further. Annual deposition rates of PAHs and EC were normalized by applying data for the ^{210}Pb flux to compensate for variable meteorological conditions. The results obtained will allow for the estimation of recent historical PAH and EC fluxes to the arctic environment.

TYPES OF ATMOSPHERIC CIRCULATION IN THE NORTHERN PACIFIC AND POSSIBILITIES OF SUPER-LONG-TERM FORECASTING

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On the basis of diurnal near-land meteorological maps of the northern Pacific aquatory for the period 1949–1990, atmospheric circulation (considered to be nonstationary) was typified. It was possible to group all synoptical situations into six types of processes: North-Western (NW), Okhotsk-Aleutian (OA), Latitudinal Aleutian (LA), Southern Latitudinal (SL), Okhotsk-Hawaiian (Honolulu), and cyclones over the ocean (CO). Analysis of their repetitions allowed us to determine the temporal variation of their effects, seasonal fluctuations, and mean and extreme durations. Certain types of situations can last continuously for two months. Succession of the next type of effect has some pecularities: For example, the NW type more often (compared to the others) inherits all other situations and itself changes mainly into the OA type.

The total duration of each type of effect was calculated for periods of one month, one season, one year, and three years. There appeared to be significant variation in the total duration of a type of effect. Thus, the existence of long-term variation due to the total duration of a type of effect is quite certain.

Simultaneously, we analyzed the long-term variation, by months, of the Bering and Okhotsk Seas ice for the period of observation from 1958 to 1990. The variation in duration of the effects of atmospheric processes and the variation in the ice by months, both graphically expressed, allowed us to determine the presence of correlations between the two processes.

A comparative analysis was carried out and a partial coefficient was calculated. After that, total coefficients of correlation were calculated and regression equations were obtained according to ruling parameters, meeting all the requirements of the super-long-term methods of forecasting. Methods of forecasting were estimated using independent data, which allowed us to get satisfactory results. The probability of the equations of regression obtained was 80–87%.

INTERRELATED GLOBAL VARIATIONS OF THE ATMOSPHERE AND NATURAL OCEAN PROCESSES: POSSIBILITIES OF INVESTIGATING THE EARTH'S ECOLOGY AND CLIMATE

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As a result of investigating atmospheric circulation in the northern Pacific, six types of processes were obtained. Studying the temporal variability of such situations allowed the determination of certain regularities. The total duration of each effect was studied. To even seasonal motion and to exclude short-term variations, successive reconstructions of yearly repetition values were carried out according to a sliding 3-year series. It appears that there exists a periodic type of variation, more exposed for some situations and less exposed for others. In addition, the total duration of processes (in days) exhibits a complexity of periodic fluctuations of cycles: 2–3 years, 5–6 years, 9–11 years, and 30 years. Thus, natural planetary processes are characterized by wave-like processes occurring over different periods; in this case, we are concerned with the whole northern Pacific and the adjacent areas of the continents.

Furthermore, fluctuations of ice in the far eastern seas were investigated. Monthly ice values expressed graphically also exhibit a wavy character. In the same way, the total quantity of precipitation was analyzed for Primorye. The situation proved to be analogous; it was also characterized by 3–5-year cycles and 9–11-year cycles. Longer term cycles are also probable; a series of observations to determine them is as yet incomplete.

Joint analyses of the variability of quantifiable characteristics of all three processes and phenomena have shown that in nature there exists a synchronous interrelationship among the phenomena. Thus, forecasting may be possible.

Analysis of each curve taken separately has allowed us to show periodic repetition of quantifiable characteristics. This, in turn, may permit interpretation of the processes in both the past and future, in order to trace the climate motion of pressure values and the processes for the long term.

Each type of atmospheric circulation is characterized by a very concrete air mass transfer in each region. Thus, it appears to be possible to determine the effect of contamination in a territory dependent on an air mass transfer and the time of its effect.

SOURCES OF AEROSOL NITRATE AND NON-SEA SALT SULFATE IN THE ICELAND REGION

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Daily aerosol filter samples have been collected continuously on Heimaey, Iceland (63.40°N, 20.30°W) since July 1991. Samples are analyzed for NO_3^-, non-sea salt $SO_4^=$, various trace metals, and methanesulfonate (MSA), a product of the atmospheric oxidation of dimethylsulfide (DMS) along with SO_2 and non-sea salt $SO_4^=$. There is a dramatic seasonal cycle in MSA concentrations, with a summer maximum of about 500 ng m^{-3}, which decreases to a few ng m^{-3} in December. This cycle coincides with huge blooms of *Phaeocystis pouchetii* and *Emiliania huxleyi* (both strong DMS producers) that often occur around Iceland in the spring and summer. Our data show that most of the time the non-sea salt $SO_4^=$/MSA ratio is very low, suggesting that aerosol non-sea salt $SO_4^=$ is largely derived from biogenic DMS. However, at times, non-sea salt $SO_4^=$ and NO_3^- concentrations increase sharply, by an order of magnitude or more, for periods of several days. These aerosol "spikes" are usually associated with the presence of a high-pressure field over western Europe and with trajectories that subsequently transport pollutants to the Iceland region. Excluding these "spikes" (i.e., about 10% of the samples), the NO_3^- average is about 0.11 μg m^{-3}, a value similar to that in the pristine South Pacific. The comparable clean air mean for non-sea salt $SO_4^=$ is 0.38 μg m^{-3}. The inclusion of pollution events results in a doubling of the mean concentrations. Thus, although pollution events are relatively infrequent, they have a substantial impact on atmospheric chemistry in this region.

THE CURRENT STATE OF BACKGROUND POLLUTION OF THE NATURAL ENVIRONMENT IN THE RUSSIAN ARCTIC AT THE UST-LENA RESERVE

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Within a radius of 1,000 km of the lower Lena River, no significant anthropogenic pollution sources can be found. The settlements of Tixi and Kyusyr present the most intensive sources. During investigations of the lower Lena River region in August-September 1992, the state of background pollution of the atmosphere, soil, vegetation, and biota was studied. Various environments were analyzed for 3,4-benz(a)pyrene, 1,12-benz(a)pyrelen, chlororganic pesticides, PCB, heavy metals, sulfur and nitrogen oxides, radionuclides, and several other pollutants. Possible emission sources were also analyzed. The studies conducted make it possible to characterize the pollution levels in all natural environments of the lower Lena River under study as low, and typical of all other arctic regions. Occasional higher pollutant concentrations can, as a rule, be attributed either to local natural sources or to pollutants from long-range atmospheric transport.

ARCTIC GAS AND AEROSOL DATA SETS FROM AGASP AND THE BARROW BASELINE STATION

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Since 1976, the NOAA baseline station at Barrow, Alaska, has continuously measured aerosol light scattering, condensation nuclei (CN), total column aerosol optical depth, and a variety of gases such as CO_2 and O_3. Each winter and spring, a strong anthropogenic air pollution influx known as arctic haze is observed in the records. These measurements have been augmented by four separate (1983, 1986, 1989, 1992) month-long aircraft field programs linking the baseline stations at Barrow, Alaska; Alert, Northwest Territories; and Ny Alesund, Spitsbergen to the arctic-wide air pollution events. Arctic haze streams have been traced from eastern Europe across the arctic basin to Barrow and Alert. The vertical structure of the haze has been related to its concentration, composition, and flow pattern measured at the surface. Many aerosol filter samples have been archived for future study. The concentration of the haze peaked in 1982 and has declined steadily to date to half of former values. The content of, and access to, these and extensive supporting arctic meteorological and climatological data sets will be outlined.

LONG-RANGE TRANSPORT OF PESTICIDES TO THE CANADIAN ARCTIC FROM AREAS OF EASTERN EUROPE AND ASIA

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The usage of various persistent pesticides on the vast territories of the former USSR, eastern Europe (the former GDR and Baltic states), and China was studied under a project implemented by UNEP/IRPTC on the initiative and with the financial support of Environment Canada. The ultimate goal of the project, covering the period 1960–1992, was to help determine a correlation between the content of the pesticides banned in Canada and the USA in the 1970s, but presently found in the Canadian Arctic ecosystems as a result of long-range atmospheric transport, and their application in the previously mentioned areas of Europe and Asia. Experts from China, Estonia, Germany, Latvia, Lithuania, the Russian Federation, and Ukraine contributed to the project. Technical and regulatory data on DDT, HCH, atrazine, aldrin, dieldrin, lindane, toxaphene, etc., were provided, in addition to data on the total production, export/import, and use of pesticides. In the context of the project, data on application rates by region, by crop, and per hectare were of special importance, as far as their use in testing of various models for the long-range transport of pollutants is concerned.

AIR POLLUTION IN POLAND AS THE SOURCE OF CONTAMINANTS IN THE ARCTIC

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National boundaries, established by humans, are not respected by air and water pollution. The distance of pollution migration depends on the type of pollutant, weather conditions, and the direction and speed of winds. Pollutants damage the natural environment, not only close to their source but all along the flowpath. Acidification, eutrophication, corrosion, ozone destruction, greenhouse syndrome, and forest decline have been found to affect various parts of the globe. The problems are caused by sulfur oxides, nitrogen and chlorine compounds, hydrocarbons, carbon dioxide, heavy metals, and many others. The European Monitoring and Evaluation Programme was set up 11 years ago. At this time, only SO_2, NO_x, and ozone levels are recorded by 90 measuring stations. Considering the number of countries and the size of our continent, the number of working stations is not sufficient. There are many small- and large-scale sources of emissions in each country. There are some especially bad situations in central and eastern parts of Europe, where the levels of emission and deposition are very high. Poland is one of the European countries suffering from extremely high levels of industrial emissions. In 1991, dust emissions were 1,163 thousand tonnes; gas emissions totalled 4,115 thousand tonnes, including 2,210 thousand tonnes of SO_2. Global emissions of gases and dust have decreased during the last 12 years, but levels of some compounds, for example NO_x, have increased by fourfold. The extent of this problem in Poland has resulted in 27 areas being declared environmental hazards, where the natural homeostasis is disturbed. These areas cover about 35,000 km^2 and are inhabited by no less than 13 million people, that is, about 35% of the population. Four areas have been declared ecological disaster areas. Because most air pollution is of the long-range and transboundary kind, some of these air pollutants may be reaching the Arctic. The global reduction of emissions will require a joint international effort.

POLLUTION TRANSPORT MODELLING IN THE ARCTIC

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Pollution in the Arctic may occur by means of long-range transport of pollutants carried by air masses. During this transport, a part of the pollutant falls out on snow, ice, and the open water area. Hence, deposited pollutants could be transported by ice drift and oceanic currents. To estimate the total pollution load for the arctic areas, it is necessary to consider the aforementioned processes, to estimate each component of transfer, and then to determine the predominant one. For this purpose, a numerical model of ocean circulation is offered. The model could serve as a tool to study the effects of pollutants on climate changes.

ARCTIC GLACIERS AS ARCHIVES OF ARTIFICIAL RADIOACTIVE CONTAMINANTS

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A significant number of atmospheric thermonuclear tests contaminated the atmosphere in the late 1950s and '60s, leading to the worldwide spread of radionuclides. Deposition of artificial radioactivity in seasonal layers of polar glaciers and ice sheets gave rise to reference levels, allowing accurate snow and firn dating. The most recent major reference level in glaciers of the northern hemisphere identifies the Chernobyl fallout. The nuclear power-based industry is also a potential source of radioactive pollution of glaciers, having, however, a more local distribution. Detailed total beta activity and tritium measurements in the vertical profiles of glaciers on Svalbard have shown that the reference levels have been well preserved over a period of 30 years, in spite of intensive melting and infiltration. Circumpolar comparison of radioactivity levels in glaciers from different parts of the northern hemisphere allows the trajectories of the radionuclide clouds to be estimated.

ELEMENT COMPOSITION AND ORIGIN OF ATMOSPHERIC BACKGROUND AEROSOL IN THE RUSSIAN ARCTIC

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Over the past decade, it has been shown that Eurasia represents the main source region of anthropogenic pollutants in the arctic atmosphere as a consequence of some natural atmospheric processes. Our investigations represent the first regular observations of aerosol element composition in the Russian Arctic. Filter samples of background aerosols were collected in the spring at Wrangel Island in 1985, 1986, 1988, and 1989, and at Severnaya Zemlya in 1985 and 1988, and then analyzed for almost 20 elements using the neutron activation method. Different statistical techniques were applied to interpret the experimental data. Variations in concentration levels, crustal enrichment factors, and ratios of Sb among the various sampling campaigns and episodes were examined. The applicability of multivariate techniques to estimate the source types and/or source regions for the various trace elements was assessed.

For the majority of the elements, the average concentrations were similar in Russian and other arctic regions. The average spring concentrations of natural (crustal and marine) aerosol components were higher in the eastern than in the central Arctic. The concentration values of the elements studied depended upon long-range air mass transport. Several anthropogenic source areas in Russia and some strong pulses of pollutants from Europe and North America were identified by comparing the sample and regional element signals.

GLOBAL USAGE OF ORGANOCHLORINE PESTICIDES

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In order to interpret present and predict future environmental concentrations of persistent organochlorine pesticides in remote regions, information on historical and future trends in emissions and use of these compounds on a global scale is required. Through contact with international agencies, literature surveys, and other means, information has been compiled on registration status, trends in regional use/emissions, and mode and time of application, as well as representative soil concentrations of 10 pesticides. Data on global usage were collected for more than 50 countries around the world. Cumulative global toxaphene usage that has been accounted for was estimated to be 450,000 tonnes; the interpolated usage was 1,330,000 tonnes from 1950 to 1993, and 670,000 tonnes from 1970 to 1993. Toxaphene is still being applied, for example, in the former Soviet Union and in Mexico. International cooperation and improved record keeping by governments are required to improve the estimates.

TRANSPORT OF CONTAMINANTS TO THE ARCTIC II: A GLOBAL DISTRIBUTION MODEL FOR PERSISTENT ORGANIC CHEMICALS

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A nonsteady-state, multi-compartmental mass balance model of organic contaminant fate is presented in which the global environment is represented by nine sequentially arranged climate zones. Each zone has an air, water, soil, and sediment compartment, described through various environmental parameters and connected by a number of advective and interfacial transport processes. Emission and degradation rates are specified for each compartment and zone. Setting up mass balances for each of the compartments results in a system of 36 differential equations, which are solved numerically to yield estimates of concentrations, masses, transport fluxes, and reaction rates as a function of time.

The model is employed to identify major principles and parameters governing the global dispersion and particularly the condensation and accumulation of persistent organic chemicals in cold regions. Namely, the importance of the following factors is assessed with the help of the model and will be discussed: (1) the major physico-chemical properties of the pollutants such as vapor pressure, aqueous solubility, Henry's law constant, and the octanol-water partition coefficient, (2) temperature, both in its spatial and seasonal variability, (3) location and amount of chemical discharge in the environment, (4) estimates of chemical degradability in various climate zones, and (5) choice of environmental descriptors such as transport rates and organic carbon contents. This discussion enables us to point out which factors have decisive impacts on pollutant enrichment and behavior in polar regions and should therefore be studied more thoroughly.

RADIOACTIVE ATMOSPHERIC CONTAMINANTS FROM LITHUANIA NUCLEAR POWER PLANT IN THE ARCTIC

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1 The support of the European Environmental Research Organization (EERO) is gratefully acknowledged.

The Lithuania Nuclear Power Plant (LNPP) has two RBMK-1500 reactors (4800 MW of power output and 1500 MW of electrical power per unit), considered to be the largest power reactors in the world. Monitoring indicates that permanent radionuclide transport exists in the near-ground layer of the air at a height of 300–800 m in a northerly and northwesterly direction from the plant. The radionuclide composition of release from the LNPP comprises ^{133}Xe, ^{85}Kr, ^{13}I, ^{132}Te, ^{134}Cs, ^{137}Cs, ^{99}Mo, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{89}Sr, etc. Chemical forms of the released radionuclides may be quite variable. Spherically shaped hot particles of aerosols containing these elements have been detected in the arctic regions. Numerical modelling of the transport, dispersion, and deposition of atmospheric contaminants was applied to a variety of situations arising from accidental releases of radioactive compounds. In addition, geographic information systems were used to relate the concentrations of radionuclides originating at LNPP to environmental variables in the Arctic.

A METHOD OF FORECASTING NONSTATIONARY THERMODYNAMIC PROCESSES AND ITS APPLICATION TO PREDICT THE ECOLOGICAL STATE OF THE CLIMATIC SYSTEM

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Long-term predictability of nonstationary components of the ecological state of the evolution of the climatic system is investigated. The climatic system, or its elements, is considered as a thermodynamic system of a flux type. The method of investigation is based on the theory of dynamic systems and nonequilibrium thermodynamics. The evolution of the system is analyzed in an n-dimensional phase space of thermodynamic variables (e.g., entropy). If observations show that a process in the system is a nonstationary cyclic process, then a change in phase volumes will reflect a change in the chosen thermodynamic function. Therefore, the evolution of the stated function of the system can be obtained as a discrete series of its values averaged over the cycle. The intervals between the values are equal to the duration of the natural cycle of the process. An analysis of the observed evolution allows us to determine the general regularities of the nonstationary processes. The stationary component is predicted using a different method. The approach described allows us to predict the evolution of the system on a climatic scale.

B. DISTRIBUTION OF CONTAMINANTS IN THE ARCTIC BIOSPHERE

Organizers: Derek Muir, Per Larsson, Eiliv Steinnes

Purpose: This session will provide an overview of the state of knowledge of contaminant deposition, fate, and bioaccumulation on a circumpolar basis. This session will address questions concerning spatial and temporal trends related to contaminants in arctic marine, freshwater, and terrestrial environments. This information is essential for understanding the possible biological effects of persistent contaminants on top predators and aboriginal peoples utilizing plants and animals as part of their traditional diets.

ORAL PRESENTATIONS

8:30 - 9:00	Ross Norstrom	Canada
9:00 - 9:30	Eiliv Steinnes	Norway
9:30 - 10:00	Claude Boutron	France
10:00 - 10:20	Sergey Mel'nikov	Canada
10:20 - 10:40	*Break*	
10:40 - 11:00	Aksel Bernhoft	Norway
11:00 - 11:20	Kristin Ólsafsdóttir	Iceland
11:20 - 11:40	Oscar Espeland	Norway
11:40 - 12:00	Chad Gubala	USA

CHLORINATED HYDROCARBONS, ESPECIALLY RELATED TO REPRODUCTION IN POLAR BEARS (*Ursus maritimus*) FROM SVALBARD

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Pollutants are transferred to the Arctic by air and water currents. It is important to discover the possible effects of these pollutants on the arctic ecosystems. The polar bear, *Ursus maritimus*, is at the top of the arctic food chain, and so is considered one of the best indicators of the degree of bioaccumulation of persistent contaminants. During the period 1978–1989, samples of fat and various tissues from 24 dead polar bears from Svalbard were analyzed for different elements and chlorinated hydrocarbons (Norheim et al., 1992). Very high levels of particular polychlorinated biphenyls (PCBs) were found, and in some bears, the PCB levels were higher than the corresponding levels connected to reproductive disturbances in seals in the Baltic Sea. Furthermore, the levels were several times higher than corresponding measurements of PCBs in the fat of polar bears from Alaska and Canada (Norheim et al., 1992; Muir et al., 1988; Norstrom et al., 1988; Norstrom, 1993).

Since 1988, the Norwegian Polar Research Institute has had a substantial tagging program for polar bears at Svalbard. Satellite transmitters are put on adult female bears, which then can be followed for up to two years. Polar bears mate in the spring and give birth the next winter. Pregnant females hibernate from December to April. Males and nonpregnant females do not hibernate. The offspring follow the mother for nearly 2.5 years, and she normally does not mate more than every third year. Information is collected on the data and location of capture, reproductive status, and nutritional condition, while age is determined by histological sectioning of teeth. Some individuals have been recaptured yearly up to four times. Blood and fat (biopsies) samples are collected from the anaesthetized bears. Levels of organochlorine pesticides (DDTs and DDEs, HCHs, chlordane, HCB) and the industrial compound PCBs (22 individual congeners) are determined in blood and fat samples; since 1990, thyroid hormones and vitamin A levels also have been determined in the blood samples. The results on levels of organochlorine pollutants, PCB congener patterns, pesticide patterns in samples of blood and fat tissue will be discussed and related to levels of thyroid hormones and vitamin A. Also, the present study aims at producing some knowledge on the possible effects on reproduction of organochlorine pollutants by integrating results from the behavioral studies, organochlorine concentrations, thyroid hormones, and vitamin A concentrations in individual female adult bears.

Muir, D.C.G., R.J. Norstrom, M. Simon, *Environ. Sci. Technol.* (1988) 22, 1071-1079. Norheim, G., J.U. Skaare, Ø. Wiig, *Environ. Pollut.* (1992) 77, 51-57. Norstrom, R.J., Proceedings of the 11th Working Meeting of the IUCN-SSC Polar Bear Specialist Group, January 25-27, 1993, Copenhagen, Denmark. Norstrom, R.J., M. Simon, D.C.G. Muir, R.E. Schweinsburg, *Environ. Sci. Technol.* (1988).

METAL DEPOSITION IN ARCTIC TUNDRA ZONES OF THE JAMAL PENINSULA, ESTIMATED BY LICHEN AND SOIL MONITORING

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Special analysis of metal content in the vegetative cover and soils of background territories is needed to estimate the deposition of metals in arctic ecosystems. The heavy metal content in the dominant indicator species of tundra communities and in the surface layer of soil was examined. The data for Fe, Mn, Zn, Cu, Pb, Ni, Co, and Cr content in lichens and mosses are also shown. These data characterize the level of metal content in background sites in the territories and in sites that have undergone anthropogenic effects. The data for total content of As, Cu, Nb, Pb, Rb, Sr, Th, Zn, Zr, and Y in the surface layer of soil (3–7 cm) of tundra mosses and lichens on the Jamal Peninsula is also shown.

GREENLAND SNOW AND ICE CORES: UNIQUE ARCHIVES OF LARGE-SCALE POLLUTION OF THE TROPOSPHERE OF THE NORTHERN HEMISPHERE BY LEAD AND OTHER HEAVY METALS

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The successive, well-preserved, dated snow and ice layers deposited in the central areas of the Greenland ice cap offer unique detailed archives of past and recent changes in the large-scale tropospheric cycles of heavy metals in the northern hemisphere. Deciphering these very valuable archives unfortunately has proven to be a real analytical challenge, due to the extreme purity of Greenland snow and ice. Reliable determination of heavy metals at the pg/g level can be accomplished only if stringent precautions are taken from field sampling to laboratory analysis to minimize and evaluate contamination and if ultrasensitive methods such as laser excited atomic fluorescence spectrometry are used. The most comprehensive, although still incomplete, data presently available are for Pb. Pb concentrations are found to have dramatically increased by more than two orders of magnitude in Greenland snow and ice from several millennia ago to the mid-1960s. The increase was especially pronounced after the 1930s, as a consequence of the massive use of Pb alkyl additives in gasoline. From the early 1970s to the present, a pronounced decrease by about one order of magnitude is observed. This decrease is due mainly to the massive fall in the use of Pb alkyl additives in gasoline in the United States, as confirmed by recent measurements of the $^{206}Pb/^{207}Pb$ ratio in Greenland snow. Although the United States alone accounted for about two-thirds of the Pb found in Greenland snows in the early 1970s, it now accounts for less than one quarter. The available data for Cd, Hg, and Zn are much sparser.

CONTAMINANTS IN WATERFOWL HARVESTED FOR CONSUMPTION IN NORTHERN CANADA

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In response to a growing concern about the quality of waterfowl harvested and consumed by Canadians, a multi-year, nation-wide survey of contaminants in waterfowl was initiated in 1988. To date, as part of that study, levels of organochlorine compounds and metals (e.g., Hg, Cd, Se) have been measured in breast muscle (and some collections of eggs) of 21 species of waterfowl and other birds harvested for consumption in northern Canada. The most ubiquitous compounds detected include PCBs, p,p'-DDE, dieldrin, and hexachlorobenzene. Dieldrin, mirex, and chlordane compounds were found mainly in birds harvested in the eastern Canadian Arctic compared with the western Canadian Arctic. The presence of compounds such as mirex suggests that at least some of the compounds found in the birds collected from northern sites can be traced to stopover or over-wintering areas in the Great Lakes. Therefore, contaminants picked up by migratory species in temperate or southern areas are transported to the north where they may become incorporated into northern food webs. Compared with birds harvested from southern sites, hexachlorocyclohexanes were found more frequently in birds collected from the northern sites. Contaminant levels were relatively higher in the species feeding on fish and invertebrates than in those species feeding primarily on vegetation, indicating a trophic effect on contaminant accumulation.

USE OF REMOTE AND GROUND METHODS FOR CONTROL OVER THE ECOLOGICAL STATUS AND TRANSBOUNDARY TRANSFER OF THE KOLA PENINSULA

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The Kola Peninsula is one of the regions intensively affected by anthropogenic activity. This region is in need of ongoing ecological monitoring. Compiling maps of vegetation disturbance and studying the field of snow cover pollution caused by industrial discharges of atmospheric pollution are effective means of ecological monitoring. Research on snow cover pollution and vegetation degradation on the Kola Peninsula test regions has shown that scientific work should be carried out in three directions to expand the automatic analysis system for the region's ecological state: (1) generalization of ground data (perennial observation of the dynamics of vegetation degradation and snow cover pollution, itinerary investigations, chemical analysis, research work in adjacent sciences, etc.), (2) obtaining the spectral characteristics of ground objects, and (3) multispectral scanning images of natural objects from satellites "Kosmos 1939" and "Almaz." The results of statistic data analysis, correlation connections, and classification of natural objects are given in this report.

REGIONAL AND TEMPORAL VARIATION OF ORGANOCHLORINES IN ARCTIC RINGED SEALS (*Phoca hispida*): A CRITIQUE OF MONITORING DATA AND THE UTILITY OF CONTAMINANT ACCUMULATION MODELS

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Ringed seal (*Phoca hispida*) blubber samples were obtained from Holman Island (western Arctic) and the Belcher Islands (eastern Hudson Bay), Northwest Territories, in order to assess regional variation in ΣPCBs, PCB congeners, and organochlorine pesticide concentrations across the Canadian Arctic. Results showed elevated mean ΣPCB concentrations in the Belcher Islands ringed seals, with higher concentrations in males than in females, and a decline in concentration over time in Holman Island male seals from 1981 to 1989-1992. Spatial and temporal trends are often masked when comparisons are based on mean concentrations, since contaminant concentrations vary with the age, sex, and physical condition of the seal (calculated as a condition index). Estimated total blubber burdens of certain chlorinated organics and ΣPCBs were found to vary significantly with age in males from both regions. ΣPCB concentrations in 1981 Holman Island male seals were not significantly different from the concentrations in the 1990 Belcher Island males when age and condition were considered. Female blubber concentrations and total blubber burden estimates for the Belcher Island population, however, showed no significant relationships with age or condition. A brief life history of the ringed seal is discussed with respect to these overall findings. Data from this study were also used to assess the effectiveness of a physiologically based contaminant accumulation model to predict contaminant concentrations in ringed seals. The development of such models will enhance our ability to more fully understand the dynamics of contaminants within the ringed seal with respect to its ecology and life history.

THE NORTHERN AQUATIC FOOD CHAIN CONTAMINATION DATABASE: A RESEARCH TOOL

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During a review of contamination in Canadian northern regions, it became apparent that a system should be developed to manage the array of information available. From that idea arose the Northern Aquatic Food Chain Contamination Database. It includes all possible contaminants for which data were available in the regions comprising the Yukon and Northwest Territories, Hudson and James Bay basins, northern Québec, Labrador, and Greenland. Data were gathered from an extensive literature review, from organizations, and from researchers themselves. More than 30 variables are attached to each mean concentration value. Some of the variables are localization, species, reference, % water, % lipids, age, sex, contaminant, standard deviation, minimum/maximum, and date of sampling. All these are subject to availability from the authors. The area under study is divided into 10 distinct regions to facilitate data management. Sample localizations are georeferenced to permit the use of geographical information systems. The database is mounted on the software *4th DIMENSION* and has been developed to provide a good degree of user friendliness. Since the database was developed for immediate and future needs, it is flexible enough for use by any researchers dealing with contaminants in northern regions.

BACKGROUND POLLUTION OF EAST ARCTIC AIR

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Monitoring of present background levels of pollutants (heavy metals, organic matter, nitrogen and sulfur compounds) in the atmosphere of the east Arctic was carried out at Spitsbergen and Severnaya Zemlya, Wrangel Island, Dunai Island (Lena River outfall), and other locations. There are spatial and seasonal differences in background levels of pollutants in polar regions of European and Asian sectors of the Arctic. Spatial features consist of higher background levels of heavy metals in the atmosphere over the Asian part of the Arctic. Seasonal differences are characterized by higher levels of industrial pollutants during winter. The main process of pollutant distribution in the subject region is well-developed meridional atmospheric transport. In this respect, the main sources of pollutants are the great industrial centers of Siberia, the Urals, and the western, northwestern, and central regions in the European part of Russia.

CESIUM-137 INVENTORIES IN ALASKAN TUNDRA AND IN LAKE AND MARINE SEDIMENTS: EVIDENCE FOR REDISTRIBUTION AND TRANSPORT

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Sampling at Imnavait Creek, Alaska (68°37'N, 149°17'W) in 1989-1990 indicated that tundra inventories of ^{137}Cs [120 mBq/cm^2 ± 28 mBq/cm^2 (s.d.); n=16] are close to measured atmospheric deposition for this latitude (-144 mBq/cm^2 as of 1985). However, ^{137}Cs inventories in tundra decrease by up to 50% along a transect to Prudhoe Bay (70°13'N, 148°30'W). Atmospheric deposition of ^{137}Cs decreased with latitude in the Arctic, but declines in deposition would have been small over this distance (200 km). In addition, observation of maximum ^{137}Cs accumulations occurring in surface layers of the most northern tundra that was sampled, rather than at 4 to 10 cm depth, as observed at Imnavait Creek, suggest a recent loss of ^{137}Cs from tundra near Prudhoe Bay. If ^{137}Cs is being remobilized in northern Alaska, increased deposition might be expected in lake and marine sediments. Sediments from Toolik Lake (68°38'N, 149°38'W) showed widely varying ^{137}Cs inventories, from a low of 22 mBq/cm^2 away from the lake inlet to a maximum of 140 to >200 mBq/cm^2 near the main stream inflow, supporting this expectation. Marine sediments collected in the Bering Sea and the Chukchi Sea, however, show lower inventories compared to tundra or lake sediments, although complete inventories are unavailable due to radiocesium buried to depths (>20 cm) beyond the sampling capabilities used.

DISTRIBUTION OF ARCTIC CONTAMINANTS

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A compilation of contaminant data from the Arctic reveals that pesticides, organochlorines, and heavy metals have accumulated, in some cases at toxic levels, around the margins of the Arctic Ocean, on neighboring land masses, in fresh and salt water, and in plants and animals who inhabit or visit this region. Preliminary data from this atlas compilation generally show highest concentrations of contaminants in Eurasia and along its shores. Elevated levels of PCBs, DDT, HCH, and heavy metals are also observed in the central Arctic Ocean and reach the shores of Canada, Greenland, and Svalbard, indicating very long-range transport. Superposition of maps depicting sulfate in air (indicative of other forms of air pollution as well) over maps showing contamination in animals and humans in northern Canada show an almost one-to-one correlation, suggesting that many of the contamination problems in northern Canada stem from long-range air transport from Eurasia. Mapping the distribution of pollutants in the ecosystem may help to clarify the possible transport pathways into and out of the arctic region.

AIRBORNE CONTAMINATION OF LAKE SEDIMENTS BY HEAVY METALS ON THE KOLA PENINSULA, RUSSIA

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Heavy metal concentrations in sediments of lakes situated at different distances from major pollution sources (Pechenganikel and Severonikel) have been determined. In order to quantitatively define a potential ecological risk, created by toxic effects of heavy metals, values for contamination degree (CD) and Hakanson's risk index (RI) have been calculated. The lakes have been divided into four classes, depending on CD and RI values and on distance from the pollution sources: (1) very high values at distances up to 10–20 km, (2) considerable, at distances of 20–30 km, (3) moderate, at distances of 50–60 km, and (4) low, at distances greater than 100 km. Typical accordance of heavy metals distribution in the sediments have been noted: areally, in the form of decreasing concentrations when moving away from the pollution sources, and vertically, in the form of decreasing contents with increasing sediment depth, which reflect changes in anthropogenic loads in the aquatic ecosystems.

METEOROLOGICAL ANALYSIS OF CHEMICAL EXCHANGE EVENTS IN THE ARCTIC BASIN

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Analysis of chemical or aerosol exchange from the troposphere to the Arctic surface is considerably more complex than similar analysis of Antarctic events. This complexity requires consideration of deep vigorous exchange, potential local contamination, and local sources of heat and moisture, which have been eliminated through site selection in most Antarctic exchange experiments. The inherent stability of near surface layers in the Arctic contributes apparent anomalies when arrival times of aerosol or gaseous contaminants are compared with conservative meteorological tracers.

Three cases are presented. One illustrates potential local contamination of air arriving through the "clean air sector" at Barrow, Alaska; the second describes deep tropospheric mixing in the Arctic basin; the third examines the diurnal variation of aerosol in the Arctic. Some criteria relative to temporal resolution of aerosol and chemical measurements relative to meteorological processes are proposed.

ENVIRONMENTAL CONTAMINANTS IN CARIBOU IN THE NORTHWEST TERRITORIES, CANADA

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Caribou (*Rangifer tarandus*) are strict herbivores with a winter diet consisting primarily of lichen. This simple food chain makes caribou a good species for monitoring changes in terrestrial ecosystem contamination. The defined ranges of herds across the Northwest Territories (NWT) enables examination of spatial trends in contaminant deposition. Baseline contaminant information is important because caribou are a major component of the traditional diet in communities across the NWT. Caribou were collected from four herds in the first year of a study to examine levels of organochlorine, heavy metal, and radionuclide contaminants. Tissue samples from 10 caribou at each location were analyzed for a suite of 63 organochlorine residues, including 43 PCB congeners and 20 pesticides, 10 heavy metals, and 7 radionuclides. Age, sex, size, and body condition were recorded. Caribou from Cape Dorset had significantly lower body fat and tissue lipid content than caribou at the other three locations. A wide range of contaminants was detected, with most compounds found at low levels. In general, organochlorine compounds were significantly higher in caribou from Cape Dorset and Lake Harbour on southern Baffin Island than in caribou from Southampton Island and the mainland community of Arviat. Total PCB residues ranged from a mean of 6.8 μg/kg (wet weight) in fat of Southampton Island caribou to 107.7 μg/kg in Lake Harbour animals. Heavy metal levels were also low with the exception of cadmium and mercury, which had community means of 14.1–33.9 μg/g and 1.3–2.9 μg/g, respectively, in kidney tissue. Collections will continue, in order to examine spatial trends and evaluate contaminant transfer through the lichen-caribou-wolf food chain.

Brandon Jones and an Arctic ground squirrel get acquainted in the field, Alaska, U.S.A.

ORGANOCHLORINES IN: (A) ADULT FEMALES WITH NEWBORN PUPS OF HARP SEAL (*Phoca groenlandica*) AND HOODED SEAL (*Cystophora cristata*) FROM THE WEST ICE AREA (S.E. Greenland) AND (B) MINKE WHALE (*Balaenoptera acutorostrata*) CAUGHT IN THE BARENTS SEA

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(A) Harp seals (10 females with pups) and hooded seals (11 females, 8 pups, and 8 adult males) were caught in the West Ice area during the breeding season in March 1990. Organochlorines [ΣPCB (22 congeners), DDTs, chlordanes, HCHs, and HCB] were determined in blubber samples and in a few milk samples. The levels of ΣPCB, ΣDDT (p,p'-DDE the major component) and chlordanes were highest in hooded seal (ΣPCB: 4.5 ppm compared to 0.9 ppm in harp seal), but harp seal contained slightly higher levels of ΣHCH and HCB. The pups of both species, with their only exposure to pollutants through their mothers (placenta and milk), contained considerable amounts of most organochlorine groups. The levels of ΣPCB, ΣDDT, and chlordanes in the pups were about 50–80% of the corresponding levels in the mothers, while the levels of ΣHCH and HCB were higher in most pups compared to their mothers, especially for harp seals. The levels of each PCB congener expressed as percent of ΣPCB were investigated in females and pups. Indications were found of selective congener uptake in the pups, though the individual differences were great. A tendency for the lower chlorinated PCBs to pass more easily through the barriers from mothers, either through the placenta or via the milk, was demonstrated. The results will be discussed according to current knowledge of feeding habits and pollution in prey organisms.

(B) Minke whales from the Norwegian scientific catch in 1988, 1989, and 1992 have been analyzed for organochlorines. The levels found are not expected to affect the population of North Atlantic minke whales. The levels of ΣPCB in blubber ranged from 1 to 4 ppm (mean: 2 ppm) in females ($n = 50$) and from 0.6 to 8 ppm (mean: 3.7 ppm) in males ($n = 48$). The catch during summer 1992 was carried out in six different areas along the northern Norwegian coast and in the Barents Sea. Some differences in the organochlorine levels were found in animals from these areas. The ongoing work on stomach contents from the same animals at the University of Tromsø may supply us with information that will explain these differences. Age and sex aspects will be discussed. We also hope to present results from analysis of some of the whales that will be caught from spring to autumn during this year's surveys. This material will provide information on possible seasonal variations of organochlorine levels in minke whales.

PARTITIONING OF ^{14}C-LABELLED 2-2'-4,4'-TETRACHLOROBIPHENYL BETWEEN FISH LIPIDS AND WATER

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The bioconcentration factor (BCF) of a hydrophobic compound is often correlated with its octanol/water partitioning coefficient. However, for very hydrophobic compounds, large discrepancies between the two variables have been reported. A possible explanation is that the lipids of an organism are more polar than octanol. The hypothesis in this study is that the lipid/water partitioning coefficient of a hydrophobic compound is dependent on the lipid composition and that it decreases as the amount of polar lipids increases. Fresh fish muscle from cod (*Gadus morhua*), perch (*Perca fluviatilis*), European flounder (*Platichthys flesus*), pike (*Esox lucius*), Atlantic salmon (*Salmo salar*), mackerel (*Scomber scombrus*), eel (*Anguilla anguilla*), and herring (*Clupea harengus*) was extracted according to Bligh and Dyer (1957). The lipid extracts were exposed to ^{14}C-labelled 2,2'-4,4'-tetrachlorobiphenyl dissolved in water of a continuous flow system. The proportion of phospholipids, detected by HPLC, was used as a measure of lipid polarity. The equilibrium concentration of ^{14}C-TCB in fish lipids with a high content of phospholipids was significantly lower than in lipids with a low content of phospholipids ($p < 0.001$). Hence, the results support the hypothesis. The results also suggest that animals with much storage fat (triglycerides), as in many arctic animals, probably have relatively high BCFs.

CONCENTRATIONS OF ATMOSPHERIC CONTAMINANTS IN ARCTIC ALASKAN LICHENS AND MOSSES AND THEIR RELEVANCE TO ARCTIC FOOD WEBS

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Lichens and mosses have been widely used to determine patterns of both local and regional contamination due to atmospheric deposition. In this paper, we compare several species of cosmopolitan Arctic Alaskan lichens and mosses in terms of concentrations of selected heavy metals, trace elements, organochlorine pesticides, and PCBs. Results of variability studies comparing concentrations of target analytes in four species (*Cetraria cucullata, Masonhalea richardsonii, Hylocomium splendens,* and *Racomitrium lanuginosum*) over a range of habitats will be presented. Results are assessed in the light of associated data for surficial soils, particularly for samples from the Northern Foothills and Brooks Range, where vegetation cover is often discontinuous and lithological influences can be significant. Vegetation data will also be discussed in terms of their relevance for two dominant Arctic Alaskan herbivores: barren ground caribou (*Rangifer tarandus*) and arctic ground squirrels (*Spermophilus parryii*).

CHLOROACETATES, PHYTOTOXIC OXIDATION PRODUCTS OF C_2-CHLOROCARBONS

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The C_2-chlorocarbon solvents 1,1,1-trichloromethane, trichlorocthene, and tetrachloroethene are ubiquitous atmospheric trace pollutants; due to their atmospheric lifetimes of several weeks to years, they are mainly degraded and their photooxidation products are deposited in the northern hemisphere. Halocarbon exposure of conifers and deciduous trees entails loss of photosynthetic pigments and affects xenobiotic metabolism, raising the question as to what extent they contribute to the induction of forest decline, observed as far north as the boreal forests of northern Finland. Chloroacetic acids are important atmospheric oxidation products of C_2-chlorocarbon solvents. Hydrochlorofluorocarbons (HCFCs), suggested as substitutes for chlorofluorocarbons (CFCs), are also oxidized to various haloacetic acids. Chloroacetic acids have been detected in the major environmental compartments, i.e., the pedosphere, hydrosphere, and terrestrial plants. Aerosol levels of monochloroacetate (MCA) are up to 400 pmol/m^3, dichloroacetate up to 20 pmol/^{3}, and trichloroacetate (TCA) up to 2 pmol/m^3. the levels of TCA in the foliage of conifers and deciduous trees in northern Finland tend to be higher than those in mountain forests in Germany. TCA concentrations and tree degeneration symptoms are correlated. MCA has been found in similar concentrations, above the toxicity threshold for some photoautotrophic organisms; fluctuations in MCA levels seem to follow those of TCA. Plant cell suspension cultures are most strongly inhibited in their growth by lipophilic derivatives of chloroacetic acids, indicating that atmospheric intermediates in chloroacetate formation may be most relevant in phytotoxicity. The high algal toxicity of haloacetic acids and their derivatives, and their potential increase in environmental burden when introducing C_2-hydrochlorofluorocarbons, urges a detailed assessment of their environmental and ecotoxicological properties.

PCBs IN GLAUCOUS GULL (*Larus hyperboreus*) AT SVALBARD

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In 1989, a number of glaucous gulls were found dead or dying in convulsions close to a rookery at south Svalbard. Glaucous gulls constitute the end of the marine food chain and are known to feed primarily on eggs and infant and adult sea birds, and occasionally on arctic cod and amphipods. In an effort to elucidate the cause of death, 12 individuals were sent to the National Institute of Veterinary Medicine in Oslo for autopsy and analysis of chlorinated pesticides and PCBs. Relatively low concentrations of pesticides were revealed. The ΣPCB^2 levels in brain tissue varied between 1 and 30 ppm (mean 20 ppm), the hepatic levels were between 1 and 31 ppm (mean 16 ppm), and the renal levels were between 0.4 and 21 ppm (mean 10 ppm). PCB numbers 118, 153, 138, and 180 constituted about 70% of ΣPCB. PCBs 118, 105, 114, 128, 157, and 156, which are all mono-ortho substituted PCBs, constituted about 40% of ΣPCB. Toxicological evaluation of the results are difficult; however, we cannot exclude the possibility that PCB could be responsible for or related to the deaths of the gulls. The results will be discussed in reference to corresponding results found in polar bear and polar fox at Svalbard, in different seal species, porpoise, and whale in the Arctic and along the Norwegian coast, and in Norwegian mothers.

POLYCHLORINATED BIPHENYL DISTRIBUTION IN CANADIAN ARCTIC SOILS: THE USE OF CONGENER SIGNATURES IN SOURCE IDENTIFICATION

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The closure of the 21 DEW Line sites spanning the Canadian Arctic has prompted a detailed assessment of the environmental impact of these facilities. As part of this assessment, in excess of 2,000 soil/sediment samples have been collected. A comparison of PCB concentrations in background samples taken from areas near the radar sites, but unaffected by direct impact (e.g., spillage), and background samples taken in remote locations (> 15 km distant) reveals evidence for short-range redistribution of PCBs. This is confirmed by utilizing principal components analysis to highlight differences in congener concentrations. The PCB congener signatures for background samples correlate well with signatures from contaminated locations on the radar sites. Information relevant to the PCB redistribution was obtained from an *in situ* PCB weathering experiment. Changes in PCB congener concentration with time are dependent on type and degree of vegetation cover and the physiochemical properties of individual PCB congeners.

THE RATES OF ACCUMULATION AND CHRONOLOGIES OF ATMOSPHERICALLY DERIVED POLLUTANTS IN ARCTIC ALASKA, USA

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Over the past decade, researchers have shown that anthropogenically derived pollutants (trace metals, organochlorines, radionuclides, etc.) are deposited upon and impact arctic ecosystems in a variety of ways. To determine the range of probable biotic effects of these pollutants, researchers must know the rate at which they enter the ecosystem. However, due to the complex deposition mechanisms and minute atmospheric concentrations of the constituents of interest, direct measurements of pollutant flux to arctic terrestrial and aquatic ecosystems are impractical. Methods of indirectly measuring the rates of pollutant accumulation, such as lake sediment stratigraphy analyses, can fill this void. A research segment of the U.S. Arctic Contaminant Research Project (ACRP) is designed to yield estimated trends in historical pollutant fluxes through examination of lake sediment stratigraphies. Present in the sediment of two Alaskan lakes sampled in April 1991 were quantifiable concentrations of numerous organochlorine compounds, including DDT and its metabolites (Sum = 0.01 to 0.50 ng g^{-1}), PCBs (Sum = 0.01 to 1.5 ng g^{-1}), and lindane (0.06 to 0.18 ng g^{-1}). These surface concentrations correspond to estimated deposition rates of 0.002 to 0.1 ng m^{-2} yr^{-1} (Sum of DDT + metabolites), 0.002 to 0.3 ng m^{-2} yr^{-1} (Sum of PCBs), and 0.012 to 0.036 ng m^{-2} yr^{-1} (lindane). The rates and chronologies of accumulation of these pollutants and others are discussed with regard to bioaccumulation within aquatic ecosystems and the process of long-range atmospheric transport.

REDISTRIBUTION OF ORGANOCHLORINE RESIDUES IN SEABIRDS

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Levels of various organochlorine residues [20 individual PCB-congeners, DDT and metabolites, hexachlorobenzene (HCB), and technical chlordane compounds] were determined in fat, brain, and liver tissues of kittiwakes (*Rissa tridactyla*) throughout a complete breeding season on Hornøya (70°N, northeastern Norway). Kittiwake body mass fluctuates greatly throughout the breeding season. These fluctuations are caused mainly by utilization of stored body fat during egg laying, incubation, and chick rearing. In general, residue levels on a lipid weight basis increase with decreasing body condition, resulting in increasing wet-weight levels in the brain. Patterns of residue levels are discussed in relation to body condition and sex and are compared between organs and eggs.

MEASUREMENTS OF SURFACE OZONE IN TROMSØ AND SVALBARD, USING AMERICAN AND RUSSIAN TYPE OZONOMETERS

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Surface ozone measurements are running at The Auroral Observatory in Tromsø. In this report, measurements throughout the winter of 1992-1993 in Tromsø and summer 1993 in Tromsø and Svalbard are given. No diurnal variations can be seen during the winter, probably because of the lack of sunlight during the polar night. However, peculiar ozone decreases occur normally during daytime when substantial traffic exists in the nearby town, and it is considered that the ozone is depleted through reactions with pollutants such as nitric oxides and hydrocarbons.

The American ozonometer has proved its reliability through worldwide use; the Russian ozonometer gives almost identical results. In addition, the Russian ozonometer is most user friendly and the price is an order of magnitude less than the American device. The Russian ozonometer is still under development, and our device is a prototype made for testing.

Lichen and moss species are carefully collected for metal analysis in the Polar Ural Mountains by Dixon Landers. The field site is near the Sob River, 70 km west of Labytangi, Russia.

PHARMACO-KINETIC MODELLING OF CONTAMINANT DYNAMICS IN ARCTIC MARINE MAMMALS

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As long-lived top predators in marine food chains, marine mammals accumulate high levels of persistent organic contaminants. Although contaminant concentrations in arctic marine mammals are generally lower than those found in marine mammals from temperate regions, the levels are high enough to be a health concern for people who rely on them as a food source. Monitoring programs developed to address this problem and to define spatial and temporal trends are often difficult to interpret, since tissue contaminant concentrations vary with age, sex, reproductive effort, and condition (i.e., blubber thickness). Although marine mammals are effective long-term integrators of ecosystem contamination, it is difficult to relate their tissue residues to the concentrations found in other environmental compartments. We have developed contaminant accumulation models for four arctic marine mammals (beluga, narwhal, ringed seal, and walrus) to provide a dynamic framework for directing and interpreting contaminant monitoring programs. The models attempt to quantify the uptake, release, and disposition of organochlorines over the entire life span of individual animals by incorporating all aspects of their life history, including growth, energetics, diet, gender, and reproduction (fetal growth, birth, lactation). The model predictions compare favorably with observed contaminant concentrations and the patterns associated with age, sex, and reproductive effort. We discuss the implications of data needed to improve the models, their applications, and their integration with food web bioaccumulation models.

CHEMICAL EXCHANGE AT THE SOIL-SNOW INTERFACE

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The exchange of soil gases to the arctic troposphere is of current interest to several fields of geophysics and geochemistry. We have begun to examine the exchange of organic vapor at the soil-snow interface, which may contribute to the general understanding of interfacial exchange processes. Soil specimens, spiked with organic solids having a great range of vapor pressure and aqueous solubility, were placed in shallow trays in contact with the surface prior to snow fall. Snow was allowed to naturally accumulate over the trays, and the temperature profile within the adjacent snow and soil was recorded. Snow specimens were collected above the trays, with a height resolution of 1-5 cm, after exposures of days to months. The specimens were analyzed with respect to density, particle size, and chemical composition. Some preliminary results are presented. These indicate that organic materials with vapor pressure on the order of 10^{-6} mm hg achieve orderly concentration profiles coordinated with the logarithm of depth, but that materials with greater vapor pressure are less orderly. An experimental comparison of the gradient and enclosure methods of measuring organic vapor permeation through snow is proposed.

IMPACT OF LONG-RANGE ATMOSPHERIC TRANSPORT OF POLLUTANTS ON HEAVY METAL CONTENT IN LAKE SEDIMENTS AND FOREST SOILS IN NORTHERN SWEDEN

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Heavy metals are emitted to the atmosphere in large amounts and transported over wide areas, causing a large-scale pollution of the environment. In addition, the ongoing acidification of soils has resulted in an increasing leaching of metals from soils to waters. Lake sediments have been used to study the present and historical input of heavy metals to lakes in Sweden. A large-scale pollution pattern has been discerned, with a decreasing load towards the north. A nationwide survey of metal content in forest soils revealed similarities in the regional distribution of some elements. These databases will also be used to assess the large-scale anthropogenic impact of heavy metal on the mor layer of forest soils and especially to evaluate the influence of heavy metal deposition in the northern parts of the country. The content of heavy metals in organic matter of the different media and the transport of heavy metals from soils to waters will be evaluated. A first assessment indicates that the content of Cd, Hg, and Pb in the mor layer have increased about 3–10 times in southern Sweden, compared to pre-industrial values, and about 2 times in the north. However, there were no indications of a general increase in the concentrations of Zn, Cu, and Cr in forest soils.

LONG-TERM DEPOSITION OF HEAVY METALS AND TRACE ORGANICS TO THE NORWEGIAN ARCTIC AND SUBARCTIC: A STUDY OF PEAT CORES

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High-resolution peat cores were collected from 10 sites throughout Norway in 1991. Cores have been radiometrically dated (^{210}Pb, ^{134}Cs, ^{137}Cs) and analyzed for heavy metals (Pb, Cd, Zn, Cu) and trace organic contaminants (PCBs, PAHs). Substantial enrichments in the surface concentrations of many contaminants have been observed even in the more remote locations of ombrotrophic bogs within the Arctic Circle. This presentation will discuss changes in deposition inputs to these ombrotrophic bogs, possible pollutant mobility within the cores, and long-range sources and transport processes. Deposition fluxes have been calculated and show marked variations spatially and temporally. There is clear evidence from the peat profiles for the transfer of both vapor phase and particulate phase contaminants to the remote Norwegian Arctic.

ELEVATED ΣPCB, ΣDDT, AND TOXAPHENE CONCENTRATIONS IN FISHES FROM LAKE LABERGE, YUKON

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Persistent organochlorines (ΣPCB, ΣDDT, and toxaphene) in fishes from Lake Laberge, Yukon, are 4 to 10 times higher than those found in the same species from other Yukon lakes and from the Northwest Territories, and are comparable to concentrations in fish from Lake Ontario. Concentrations have forced Health and Welfare Canada to close all commercial and native subsistence fisheries on this lake, jeopardizing the livelihood of people in the surrounding communities. The sources of these contaminants are presently unknown, but are believed to be a combination of local inputs and long-range transport and deposition. This study examines the hypothesis that the elevated levels of organochlorines in the fishes are due to unique characteristics of the Lake Laberge food web, compared to the food webs in other lakes in the region. Laberge has been heavily fished for over a century and receives nutrients from the sewage from the city of Whitehorse. Previous studies on Laberge reveal that the lake trout are very low in number, high in fat content, and solely piscivorous, unlike those from other lakes on the Yukon River system. Naturally occurring stable isotopes of nitrogen and carbon are being used to characterize the food webs of Laberge, Fox, and Kusawa lakes. Briefly, nitrogen isotopes determine the average trophic position of organisms, whereas carbon isotopes are useful in determining the origins of the diets of organisms and the original sources of carbon in the system. We combine these stable isotope measurements with ΣPCB, ΣDDT, and toxaphene concentrations to quantify and qualify the transfer of contaminants through the biota and to determine if food web differences are responsible for the elevated levels of contaminants in the biota from Lake Laberge.

Late winter ice on Arctic Alaska lakes is usually two meters thick. Chad Gubala holds the ice auger on Shrader Lake in the Arctic National Wildlife Refuge, Alaska, U.S.A.

PESTICIDES IN SWEDISH PRECIPITATION

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A cooperative Nordic project was initiated in 1990 to investigate the possible deposition of currently used pesticides through rainfall. Information will be restricted to the Swedish part of the investigation. Rainwater is collected at three locations in Sweden. The first two sites were Scania, in the far south, and Uppsala, 500 km further north. In 1992, the study was expanded to include the third location, in the far north at Abisko, 200 km north of the Arctic Circle, in a remote area, far away from sites of pesticide use. The rainwater samples are analyzed by two separate screening procedures, the phenoxy acid method and the multi-residue method. Identification of the pesticides is confirmed by mass spectrometry. Extraction of large volumes of rainwater, together with modification of the methods originally used for analysis of surface water samples, has lowered the detection limit to 1–50 ng/L for 25 selected pesticides, including metabolites. Twenty pesticides were detected during the first two years (1990–1991), with phenoxy acids, atrazine, and HCHs being the most commonly detected. Peak concentrations occurred in May–June, during the most intensive period of spraying applications. A greater proportion of pesticides was found at the most southern site, in Scania, the province having the highest use of pesticides in Sweden. It is also the site closest to other European countries where pesticides prohibited in Sweden are still being used. Results from the investigation in 1992 will be presented at the symposium. The results show that currently used pesticides, like the phenoxy acids, can be detected in Swedish rainwater, along with pesticides such as 2,4-D, atrazine, and HCHs, which are not registered for use within the country. This indicates a transboundary atmospheric transport and deposition of airborne organic pollutants in Swedish rainfall.

GEOGRAPHICAL DISTRIBUTION AND IDENTIFICATION OF $MeSO_2$-PCB/DDE METABOLITES IN POOLED POLAR BEAR ADIPOSE TISSUE IN WESTERN HEMISPHERE ARCTIC AND SUBARCTIC REGIONS

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The polar bear (*Ursus maritimus*) is the principal mammalian predator at the top of the arctic food chain. Because of the high fat diet of the polar bear, consisting mostly of ringed and bearded seal blubber, the species is a good candidate for studying the presence and geographical distribution of lipophilic organochlorine contaminants. Throughout the Canadian Arctic and Subarctic regions, the geographical distribution of persistent PCBs and DDT in polar bear adipose and liver tissues has been well documented. PCB-99, -153, -138, -180, -170, and -194 were the dominant congeners, all containing combinations of 2,4, 2,4,5, 2,3,4, or 2,3,4,5 chlorine substitution on each of the phenyl rings. Polar bears do not accumulate PCBs with nonchlorinated meta-para (3,4) positions, which are present in ringed seal. However, concentrations of methylsulfone ($MeSO_2$-)-PCB metabolites of the 3,4-unsubstituted class of PCB have been found to be similar to that of nonmetabolized PCBs in polar bear tissues. In all cases, these persistent metabolites possessed a $MeSO_2$- functional group in the 3 or 4 position and chlorines in the 2,5- or 2,5,6- positions on one phenyl ring. The relative contributions of formation in polar bear versus bioaccumulation of $MeSO_2$-PCB metabolites from ringed seal is presently unresolved. Similarly, DDE, a normally recalcitrant chlorinated aromatic compound and metabolite of DDT, is metabolized to 3-$MeSO_2$-DDE in polar bear. Pooled polar bear adipose samples, containing contributions from 3 to 10 individuals each, from 5 roughly equidistant zones spanning eastern Greenland to the Bering Sea, were analyzed for PCBs and DDE and their $MeSo_2$-metabolites. The total levels of each class of compounds showed a general west-to-east increase along a band of latitude between 65°N and 70°N. In general, this was true for most individual congeners. Total PCBs and $MeSO_2$-PCBs ranged from ~1.74 to ~13.73 mg/kg and ~0.32 to ~1.06 mg/kg in fat, respectively, from west to east. The sum of $MeSO_2$-PCBs was ~11% ± 4% of total PCBs and therefore relatively constant and independent of longitude in the western hemisphere. Due to the high levels and toxic effects of some $MeSO_2$-PCBs and -DDE suggested by laboratory studies, the toxicological significance of these compounds to wildlife and humans that consume them may be much greater than presently recognized.

PESTICIDES IN PRECIPITATION IN NORWAY

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The literature from the last few years gives us many examples of pesticides found in precipitation, including areas where they have not been used (nonpesticide areas). It is known that persistent organic chemicals such as DDT and PCB have been transported over long distances in the atmosphere; in the middle sixties, the first articles about pesticides in precipitation, concentrating on lindane, dieldrine, and DDT, were published by British scientists. Some years later, such chemicals were also found in snow in arctic areas.

Since 1991, Norway has been engaged in a project aimed at: (1) getting a picture of the deposition of different pesticides, as well as concentrations in precipitation, and (2) building knowledge and methodology for a better prognostication concerning important factors in the transport system via the atmosphere, and (3) estimating ecological consequences and evaluating them in relation to pollution.

Rainwater from two stations was analyzed for 8 pesticides (herbicides, insecticides, fungicides) at a detection level varying from 10 to 5 ng/L. Pesticides were found in amounts varying from a maximum of 320 ng/L for the phenoxyacid MCPA and 43 ng/L for lindane. The point of time for the findings indicated a local spraying source for the phenoxyacids; however, this was not the case for lindane, which was detected throughout the year. Most of the lindane findings were detected in precipitation when the wind was blowing from east-southeast.

ASSESSMENT OF THE EFFECTS OF GAS PRODUCTION ON VEGETATION IN THE NORTH OF WESTERN SIBERIA

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The construction and operation of a gas production complex in the north of Western Siberia has led to air, water, and soil contamination. In all cases, pollutants produce some effect on the vegetation. The complex emits nitrogen and carbon oxides, dust, methane, heavy metals, etc. Nitrogen oxide is the main pollutant. changes in the composition and the concentration of pollutants in the soil and the vegetation cover (dwarf shrubs, mosses, and lichens) were analyzed at various stages of the construction and operation of the gas production complex. The structure of the lichen groups was also analyzed in relation to various concentrations of pollutants in the air and in the lichens. An attempt is made to clear up the effect of nitrogen saturation on the vegetation of oligotrophic bogs. An atmospheric pollution monitoring systems is suggested.

POLLUTION OF ARCTIC RIVER SYSTEMS UNDER GOLD AND TIN FIELDS PROCESSING

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The operation of mining enterprises results in the processing of millions of cubic meters of rock, the major part of which is ice-saturated loams. The intensive thermoerosion related to mining operations creates anthropogenic mobile relief on the affected cryogenic base. Technogenic changes affect atmosphere, natural waters, soil, and vegetative cover. Negative results of industrial exploitation have a local character, while water system pollution is of a regional character, occurring for tens and hundreds of kilometers, sometimes reaching the continental shelf. Activation of physico-chemical, biogeochemical, and dispersive high icy fields at the hypergene zone leads to a rapid transformation of hypergenic matter and intensive transference and penetration to rivers. Technogenic fluxes of dissipation appear, superimposing geochemical anomalies on nature. Waters experiencing full technogenic metamorphization, with abnormal concentrations of heavy metals, are formed near fields. Technogenic runoff contains a great amount of mineral suspension that strongly prevails over ionic runoff. Suspended sedimentation of technogenic water systems contains a wide complex of chemical elements. Evacuation of mineral suspension by water fluxes increases by three or four orders of magnitude. Modulus of drifts runoff reaches 10–15,000 t/km^2. Increase in air temperature and natural waters during warm seasons takes place simultaneously with sharp increases in the amount of evacuation of heavy metals, largely at suspended runoff.

SURVEY OF TRACE ELEMENTS IN LAKE WATERS OF FINNISH LAPLAND USING ICP-MS TECHNIQUES

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Water samples for trace element analyses have been collected from small Finnish headwater lakes in 1992 in connection with the national monitoring program on LRTAP and surface water acidification. The lakes are situated all over the country, mostly in acid-sensitive upland areas. Similar surveys within the last 10 years in northern Scandinavia have shown concentration levels near the detection limits of the methods used (FAAS, GFAAS, ICP-AES). However, changes in water quality due to anthropogenic activities seem to control the concentrations of heavy metals in lakes. This has been demonstrated in detailed catchment studies and also found in regional surveys. Acidic conditions favor the enhanced concentration of several metals (e.g., Al, Cd, Zn, Mn) in the water phase. Another driving variable is humus content in water, which explains much of the variation of Cu, Fe, Al, Ni, and Pb. The low concentration levels of heavy metals set special demands on sampling, sample handling, and analyzing. In order to study the fluxes of several heavy metals reliably and to calculate budgets on a catchment scale, a sensitive and rapid method is needed. Inductively coupled plasma mass spectrometry (ICP-MS) is a relatively new method for multi-element analysis and is ideally suited to the analysis of waters, because the majority of elements can be detected at the 0.01 $\mu g\ L^{-1}$ level. This method was applied to the survey material sampled in 1992. The data of this survey is compared to earlier surveys and the differences between northern Finland and other parts of the country are highlighted.

IMPACT OF COAL-FIRED POWER STATION ON VEGETATION AT BARENTSBURG, SVALBARD

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The Nordic countries and the Russian Federation include arctic territories with considerably well-developed local industry (smelters, power plants, etc.). Nowadays, fragile arctic ecosystems are influenced not only by atmospheric pollutants originating in lower latitudes, but also by pollutants from local sources.

To study the impact of local point sources on arctic vegetation, concentrations of selected air-borne pollutants in some compartments of terrestrial ecosystems were measured in Svalbard. The main objective of our study was to evaluate the impact of Barentsburg's power station emissions on surrounding vegetation and to measure the accumulation depending on (1) distance from pollution source, (2) altitude and relief, and (3) component of ecosystem (lichens, mosses, litter). We also were interested in restoration of vegetation after cessation of local pollution. For this purpose, comparable samples were collected at Kolsbay, where coal mining activities ceased several years ago. To get background data on the content of pollutants in lichens, mosses, and litter, samples were taken from different locations in Svalbard.

The most important pollutants (Cu, Zn, Mn, Fe, Pb, Cd, Ni, Co, Cr, Sr, Li, and total sulfur) were analyzed in samples. The highest concentrations of pollutants were measured in litter, decreasing as follows: litter > mosses > lichens. Total sulfur content was almost equal in litter samples from the Barentsburg and Kolsbay areas and a little higher than in samples from other locations. The highest pollutant content in lichens and mosses was estimated for samples from the Barentsburg area.

ATMOSPHERIC DEPOSITION AND BIOCONCENTRATION OF CHLORINATED ORGANIC COMPOUNDS IN THE LAKE BAIKAL ECOSYSTEM

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Samples of air, water, and biota were collected at Lake Baikal, Russia, during June 1991 to determine concentrations of chlorinated pesticides and polychlorinated biphenyls (PCBs) and to estimate the gas flux across the air-water interface. Air concentrations of hexachlorobenzene (HCB), chlordane, and chlorinated bornanes (CHB) were similar to measurements from arctic regions; however, hexachlorocyclohexane (HCH), DDT, and PCB levels were higher than expected, suggesting possible local sources. Results from flux calculations ranged from an average deposition of 135 ng m^{-2} day^{-1} for HCH to average volatile emission of 45 ng m^{-2} day^{-1} for 4-Cl PCBs. Biological samples, including an endemic whitefish or omul (*Corogonus autumnalis*), a pelagic planktivorous sculpin (*Cotto comephorusinermis*), and Baikal seal, indicated that the Baikal seal, at the highest trophic level, had the highest levels of organochlorine compounds, ranging from 0.07 ng mg^{-1} lipid HCB to 64.7 ng mg^{-1} lipid ΣDDT.

PCBs IN ARCTIC SEABIRDS FROM THE SVALBARD REGION

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Previous studies have indicated the presence of high levels of organochlorines, especially PCBs, in some species of arctic seabirds. In particular, the glaucous gull (*Larus hyperboreus*) has shown high levels of organochlorine contamination. We present data on total PCB and congener-specific PCBs in liver samples of four species of seabirds from the Svalbard region. Two of the species were sampled both in the vicinity of the mining town, Longyearbyen, where PCBs have been used in the past, and in the remote region of Nordaustlandet. We compared the levels obtained from these two localities in order to test if there was any indication of local contamination in the Longyearbyen area. No significant difference was found in total PCB between glaucous gulls collected at Longyearbyen and Nordaustlandet (grand mean ± s.d. = 15.59 ± 21.53 μg/g wet weight, n=30). However, in both species, we found significantly higher levels of higher chlorinated CBs in the Longyearbyen samples, and higher levels of lower chlorinated CBs in the samples from Nordaustlandet. This indicates that the birds sampled at the two localities might have been contaminated by different sources. Local contamination in the Longyearbyen area is one of several possible explanations for this difference. Total PCB levels in common eiders (*Somateria mollissima*) and Brünnich's guillemots (*Uria lomvia*) were in the same order of magnitude as in the black guillemots (mean ± s.d. = 0.04 ± 0.04 μg/g, n=11; 0.08 ± 0.04 μg/g, n=8, respectively).

SPATIAL AND TEMPORAL VARIABILITY OF LEVELS OF HEAVY METALS, ORGANOCHLORINES, AND PETROLEUM HYDROCARBONS, INCLUDING PAH, IN THE SNOW-ICE COVER AND SURFACE WATER OF THE SEAS OF THE RUSSIAN ARCTIC

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The presentation summarizes data on the levels of organochlorines, PAH, petroleum hydrocarbons, and heavy metals in surface waters and snow-ice cover of the seas of the Russian Arctic. The data allows us to identify stable zones of enhanced concentrations, observed from year to year, of the contaminants listed in the environmental compartments of the Siberian shelf seas. The results obtained provide sufficient evidence that the levels of contaminants are within the regional geochemical background and that the spatial distribution of their concentrations depends to a great extent on the character of the prevailing atmospheric circulation, the hydrological conditions formed, and the presence of local input sources. Maximum pollutant concentrations are characteristic of the coastal sea regions and can reach 3 mkg/kg for Pb and Cd, 8 mkg/kg for Cu, 100 mkg/kg for petroleum hydrocarbons, 2 mkg/kg for PAH, and 20 mg/kg for organochlorines. The data presented result from a 10-year cycle of field observations.

ACIDIFICATION IN LAKES AND RIVERS OF THE KOLA SUBARCTIC

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Kola North is exposed to the most severe impact of the acid-generating matters in comparison to the other regions of the Arctic and Subarctic, due to emissions from Pechenganickel and Severonickel smelters. The climatic and geologic conditions of waters forming characterize this territory as extremely sensitive to acidic impact and provide a number of specific indices of the development of the acidification process in lake water. Among 360 lakes examined, 13.5 were acidified (pH < 5) and 30% were in critical condition (ANC < 50 μeq/L; HCO_3 < SO_4). Most of the acidified lakes are found among the small mountain and tundra lakes. In flood periods, short-term acidic episodes (pH < 5) occur in mountain streams. These episodes, in combination with heavy metals, are especially dangerous for Subarctic fauna. A real trend towards a decrease in alkalinity was observed in the region's large rivers, which indicates profound transformations in the large water catchments.

LEVELS OF PERSISTENT CHLORINATED HYDROCARBONS AND HEAVY METALS IN WATERFOWL AND SOME AQUATIC IOTA FROM SPITSBERGEN AND HOPEN

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To determine background levels of chlorinated hydrocarbons and heavy metals in Svalbard prior to expected increased industrial activity in connection with exploration for oil, representative samples were taken from waterfowl and organisms in the aquatic food web at Spitsbergen and Hopen in 1984. Concentrations of hexachlorobenzene (HCB); hexachlorocyclohexanes (HCH); polychlorinated biphenyls (PCB); the pesticides DDE, DDD, DDT, chlordane, toxaphene, aldrin, dieldrin, endrin, and methoxychlor; total extractable persistent organically bound chlorine (EPOCl); and the heavy metals lead, copper, mercury, zinc, cadmium, and selenium are presented. On the whole, the levels are similar to or lower than those found in corresponding samples from uncontaminated areas of Greenland and Norway. EOPCl values ranged from 90 to 750 mg/kg in the extractable liver lipids from waterfowl and from 5 to 41 mg/kg in ascidian, shrimp, fish filet, and seal blubber and liver samples. In samples from the glaucous gull, between 35% and 40% of the organically bound chlorine could be accounted for by the chlorine in HCB, DDE, and PCB, whereas these compounds comprised less that 5% of the EOPCl in the other waterfowl samples. The percent EOPCl due to the chlorine contained in the identified compounds varied between about 1% for shrimp to 28% for bearded seal blubber. Part of the unidentified EOPCl may be due to polar metabolites or other chlorinated compounds that do not survive the cleanup procedures used in this study. As expected, the concentrations of persistent chlorinated xenobiotics and heavy metals increased with increasing position in the food web.

HISTORICAL PROFILES OF SEMI-VOLATILE ORGANOCHLORINES IN ARCTIC LAKE SEDIMENTS: SUPPORT FOR THE "COLD-CONDENSATION" HYPOTHESIS?

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The temporal trends of most semi-volatile organochlorines (OCs) such as PCBs, DDT, toxaphene, chlordanes, hexachlorocyclohexanes (HCH), and hexachlorobenzene (HCB) in the Canadian Arctic are not well known. PCB and DDT concentrations have declined in ringed seals and seabirds since the early 1970s and analysis of glacial snow cores has indicated declines in HCH and dieldrin. But are these declining concentrations occurring for all OCs at all latitudes and at the same rate as in the mid-latitude regions of North America and Europe? The cold condensation hypothesis recently articulated by Wania and Mackay suggests that more volatile OCs are more prominent in polar regions and that temporal trends in deposition of these contaminants differ from trends in temperate regions. In this study, we collected sediment cores with the objective of examining latitudinal and temporal differences in deposition of a wide range of OCs. Sediment was collected with a specially constructed box corer (30×30 cm) or with large (16 cm) KB corers from the deep basin of lakes at the Experimental Lakes Area (49°30'N), Saqvacquaq (63°39'N), Cornwallis Island (75°07'N) and northern Ellesmere Island (Lake Hazen; 82°N). Cores were carefully sliced at 0.5 or 1.2 cm intervals and stored in "WhirlPak" bags. Sediments were freeze-dried in their sampling bags. Dried sediment was assayed for ^{210}Pb, ^{137}Cs, and ^{6}Be and the profile of radionuclides was used to date each slice. Sediment (10 g) was Soxhlet extracted with dichloromethane (DCM), sulfur was removed by use of activated Cu, and extracts were chromatographed on Florisil columns to separate PCBs, HCB, and DDE from most chlordane, toxaphene, and HCH components. Florisil eluates were analyzed by high-resolution GC-ECD (60 m × 0.25 mm i.d. DB-5 columns with H_2 carrier gas) with confirmation by GC-MS. Highest concentrations of total DDT were found in ELA (49°) sediments in slices dated to 1970 and lowest concentrations in Lake Hazen. PCBs (total congeners) were present at highest concentrations in high organic carbon sediments from Hawk Lake (66°) and at ELA. The profiles of major OCs were shifted temporally in the northern sediments. Both PCBs and DDT were at highest concentrations the most recent slices (1980s) of cores from high Arctic lakes (at 75°N and 82°N), whereas peak concentrations were reached earlier (in the 1970s) at more southerly locations. High arctic lake sediments had greater proportions of lower chlorinated PCBs, in comparison with ELA and with published results for Lake Ontario and Lake Superior. The results generally support several of the predictions of the "cold condensation" hypothesis.

THE USE OF LICHENS IN ATMOSPHERIC DEPOSITION STUDIES WITH AN EMPHASIS ON THE ARCTIC

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Lichen-dominated ecosystems occur extensively in arctic regions, where they support extensive caribou and reindeer herds. Because they lack root systems or other absorptive organs, they are dependent primarily on atmospheric sources of nutrients. As a consequence, they are efficient accumulators of atmospheric deposition, as was so well demonstrated in the accumulation of radionuclides along the lichen-caribou-human foodchain during the 1960s. As surrogate receptors for atmospheric deposition, lichens provide an excellent matrix for accumulation, because they grow slowly and do not alter their morphological form with time to the same extent that vascular plants do. This paper reviews the physical, chemical, and biological principles behind accumulation and retention of atmospheric deposition by lichens. In addition, published data from arctic regions on deposition of acidic aerosols, organics, radionuclides, and trace elements are summarized.

Russian scientists Yuri Shur and Tatyana Vlasova take a break in front of a remote cabin in the Arctic National Wildlife Refuge, Alaska, U.S.A.

DISTRIBUTION OF CHLORINATED HYDROCARBONS IN THE ARCTIC BIOSPHERE

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Chlorinated hydrocarbons (CHCs), such as PCBs, DDT, and toxaphene, are the class of arctic airborne organic environmental contaminants that cause the most concern. Many CHCs resist environmental and biological degradation, many tend to bioconcentrate from water and biomagnify in food chains, and some are toxic. Biota at the top of the food chain, including humans, therefore have the highest potential risk. By far the largest database for the arctic biosphere is for marine mammals. CHCs have been found in fur seal (*Callorhinus ursinus*), ringed seal (*Phoca hispida*), hooded seal (*Cystophora cristata*), bearded seal (*Erignathus barbatus*) walrus (*Obdobenus rosmarus divergens*), beluga (*Delphinapterus leucas*), narwhal (*Monodon monoceros*), porpoise (*Phocoena phocaena*), and polar bear (*Ursus maritimus*). There are also some studies on fish and invertebrates, but these are much more limited in nature, and this presentation will concentrate on marine mammals. The best temporo-spatial distribution data are for PCBs and DDT in ringed seal, beluga, and polar bear. There are no data for the Russian Arctic, therefore it is possible to discuss only distribution in the western arctic hemisphere. On a fat weight basis, sum of DDT-related compounds (S-DDT) and PCB levels are lowest in walrus (< 0.1 μg/g), followed by ringed seal (0.1–1 μg/g range). Levels are an order of magnitude higher in beluga and narwhal (1–10 μg/g range). Polar bears have levels of PCBs similar to those in cetaceans (1–10 μg/g), but with a much simpler congener pattern. DDE levels are lowest in polar bear, indicating rapid metabolism. Comparison of levels of S-DDT and PCBs in arctic beluga and ringed seal with those in beluga in the Gulf of St. Lawrence and ringed seal in the Baltic Sea indicate that overall contamination of the arctic marine ecosystem is 10–50 times less than in the northern hemisphere, temperate latitude, coastal marine environment. Spatial distribution of residue levels in polar bears indicates a gradual increase from Alaska east to Svalbard, except that PCB levels are significantly higher in eastern Greenland and Svalbard. S-DDT and PCB levels declined about threefold and sevenfold, respectively, in female ringed seal in the Canadian high Arctic between 1972 and 1989. DDT levels decreased about fourfold in adult male polar bears in western Hudson Bay over the same period. There were no significant changes in PCB levels, although there has been a decreasing tendency since 1983. Other contaminants, such as HCHs, HCB, toxaphene and TCDD, tris(4-chlorophenyl)methanol will also be discussed.

ORGANOCHLORINES IN EGGS OF WHITE-TAILED SEA EAGLES IN NORWAY 1974-1992

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The white-tailed sea eagle (*Haliaetus albilcilla*) is a top predator on the western and northern Norwegian coasts, preying mainly on marine fish and coastal birds. It was persecuted until 1968, when it was totally protected. Since 1974, samples of eggs have been analyzed at the Norwegian Veterinary Institute for organochlorine content. PCB is the dominating organic pollutant. In recent material, 17 different congeners have been quantified by capillary column gas chromatography. DDT is present in quite high concentrations, almost completely broken down to DDE. There seems to be an effect of shell thinning in recent material, probably caused by DDE. Contrary to expectations, neither the PCB nor the DDE concentrations seem to decline. Different compounds in the chlordane group are present in quite high concentrations. Lower, but measurable amounts of dieldrin, HCB, and HCH have also been detected.

ORGANOCHLORINE RESIDUES IN GYRFALCONS FROM ICELAND

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Very little information is available on the existence of persistent organochlorine compounds in Icelandic wildlife. The levels of 10 isomers (28, 31, 52, 101, 105, 118, 138, 153, 156, 180) of polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), hexachlorocyclohexane (HCH), and total dichlorodiphenyltrichlorethane (DDT and its metabolites, DDE and DDD) were measured in breast muscle (n = 59) and liver (n = 13) tissues of gyrfalcons (*Falco rusticolus*) found throughout Iceland during 1979–1990. The levels of organochlorines were very similar in breast muscle and liver tissues. The levels of ΣPCBs, HCB, and ΣDDT were about 1 mg/kg, 0.03 mg/kg, and 0.5 mg/kg, respectively in breast muscle in the first year of life and increased tenfold during the second year. The levels of HCH were low or nonexistent, and only the α-isomer could be detected. DDT was found predominantly as DDE. The biggest variable in the levels of organochlorines in the gyrfalcons seemed to be their age, so that the effects of sex, location, year, and nutritional status were inconclusive. The levels of organochlorines in ptarmigans (n = 5), the most common prey species of the gyrfalcon in Iceland, were found to be nonexistent. Therefore, the source of the organochlorine contamination in gyrfalcons in Iceland has still not been determined.

KINETICS OF ORGANOCHLORINES IN THE ADIPOSE TISSUE, SERUM, AND MILK OF FREE-RANGING POLAR BEARS

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Results will be presented on the dynamics of polychlorinated biphenyls and other halogenated compounds in polar bear adipose tissue, blood, and milk over an annual cycle of hyperphagia and fasting. Polar bears eat seals primarily and are, therefore, at the top rung of the arctic marine food chain. As such, they are subject to bioaccumulation of polychlorinated biphenyls and other lipid soluble halogenated organic compounds that have been linked to reproductive failures in other marine mammals. Polar bears undertake a brief (6–8 week) period of hyperphagia in late spring when extensive adipose tissue is deposited, while during much of the remaining year, the bears are forced to fast. I propose that the resulting annual fluctuation in size of the adipose tissue pool has a large effect on the dynamics of lipophilic contaminants in polar bears. Also, it is possible that the biochemical changes associated with fasting in polar bears influence the rate of metabolism of organochlorines. Until now, assessment of contaminant loads in polar bears has been from animals killed during a brief hunting season in autumn or winter when fat reserves are low and the animals sampled are mainly young males. Innovative field and laboratory techniques have been used to determine the fate of organochlorine contaminants and their metabolites in the adipose tissue and serum of all reproductive classes of polar bears throughout the year and to determine the rate of transfer of organochlorine contaminants and their metabolites from mother to cubs via milk. The kinetics of organochlorine contaminants are not known for any mammal species and must be understood to properly assess the effects of contaminants on top predators in the marine food chain.

Susan Allen-Gil performs non-lethal field surgery on an Arctic ground squirrel to collect tissue samples for contaminant and hormone analysis, Alaska, U.S.A.

ENVIRONMENTAL CONTAMINANTS IN HARVESTED MINK IN THE NORTHWEST TERRITORIES, CANADA

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The mink (*Mustela vison*) is a top trophic level species that readily bioaccumulates environmental pollutants, and as such is considered to be a sensitive indicator of ecosystem health. In the first year of a study conducted to examine levels of organochlorine and heavy metal contaminants in mink in western Northwest Territories, carcasses were collected from trappers from three communities during winter 1991-1992. Tissue samples from 20 mink from each community were analyzed for a suite of 63 organochlorine residues, including 43 PCB congeners and 20 pesticides, and residues of 10 heavy metals. In an attempt to link contaminant levels to population effects, carcasses also were examined for sex, age, and body condition; winter diet was also assessed. A total of 510 mink carcasses was collected. Overall, contaminant levels were low compared with those in other mink examined in North America. Total PCB residues ranged from a mean of 8.9 $\mu g/kg$ (ppb) (wet weight) in the livers of Inuvik mink (the northernmost community) to 95.5 ppb in mink from Ft. Rae (the southernmost community). Heavy metal residues also were comparatively low, with the exception of mercury, which was at moderate levels [community means of 1.0–3.0 $\mu g/g$ (ppm)]. There was a general trend of decreasing contaminant levels with increasing latitude; Ft. Rae mink had slightly higher residue levels than mink from Ft. Good Hope, and Inuvik mink were significantly lower than those in other communities. The population indices, coupled with comparatively low levels of contaminants, suggest little or no effects on mink reproduction or population health as a result of these contaminants. Collections will be continued, to examine spatial and temporal trends in contaminant levels and to identify dietary sources of contaminants.

EFFECTS OF LOCAL AND DISTANT CONTAMINANT SOURCES: POLYCHLORINATED BIPHENYLS AND OTHER ORGANOCHLORINES IN BOTTOM-DWELLING ANIMALS FROM AN ARCTIC ESTUARY

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Elevated concentrations of organochlorines in the tissues of large marine predators in the Canadian Arctic are well documented. Typically, PCBs and other organochlorines originate in more industrialized parts of the northern hemisphere, enter the Arctic, and are subsequently biomagnified. This paper will document some of the first data on the composition and distribution of chlorinated organic compounds in some arctic coastal animals found at lower levels of the marine food chain. Organisms include bottom-dwelling invertebrates: clams (*Mya truncata*), mussels (*Mytilus edulis*), sea urchins (*Strongylocentrotus droebachiensis*) and fish: sculpins (*myoxocephalus quadricornis*). Most of the samples were collected in the vicinity of Cambridge Bay, Northwest Territories, but confirmatory evidence was also acquired near another inhabited area, Hall Beach, Northwest Territories, and at a reference site, Wellington Bay. Concentrations in sediment, water, and tissues, as well as spatial distributions and congener signatures, confirm that the organochlorines come from both distant and local (hamlet and DEW Line) sources. A clear pattern of biomagnification is evident.

THE CARBONACEOUS PARTICLE RECORD IN POLLUTED AND "CLEAN" ARCTIC LAKES COMPARED WITH THAT OF MOUNTAIN LAKES IN EUROPE

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Lake sediments contain a record of lake, catchment, and atmospheric history. Spheroidal carbonaceous particles produced by high-temperature combustion of fossil fuels are found in high concentrations in the upper levels of lake sediment cores taken from areas of high acid deposition. In many parts of Europe, the sediment record of these particles showing the onset of industrialization correlates well with the record of acidification as indicated by diatom analysis. The distributions of these particles can give an indication of the extent to which a single lake or an entire region has been contaminated by airborne pollutants derived from other fossil fuels (e.g., sulfur), both spatially and temporally. The carbonaceous particle records of two polluted arctic lakes, Shuonijavr and Stepanovichjärvi on the Kola Peninsula, Russia, are compared with those of a "clean" site, Arresjøen, on Spitsbergen. Particle profiles from mountain lakes in other areas of Europe and Asia thought to be "clean" and remote, have been studied as part of other research programs, including the EC AL:PE program. Some of these sites have been found to contain significant concentrations of particles and the temporal profiles compare well with national fossil fuel combustion figures. The particle records of these mountain lakes are compared with those from the arctic sites.

CHLORINATED HYDROCARBON RESIDUE LEVELS IN SEABIRDS FROM THE BARENTS SEA AREA

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Different groups of organochlorines [PCBs (sum of 22 individual congeners), DDT and metabolites (sum DDT), technical chlordane compounds (sum CHLOR), hexachlorocyclohexane isomers (sum HCH), and hexachlorobenzene (HCB)] have been identified in fat, liver, brain, and muscle tissues of seabirds, collected in summer 1992 from five seabird colonies in the Barents Sea (western coast of Spitsbergen, coast of northern Norway, Bear Island, western coast of Kola Peninsula, and Frans-Josef Land). Examined species included different ecological groups of birds: glaucous gull (*Larus hyperboreus*), great blackbacked gull (*L. marinus*), herring gull (*L. argentatus*), kittiwake (*Rissa tridactyla*), puffin (*Fratercula artica*) fulmar (*Fulmaris glacialis*), Brunnich's guillemot (*Uria lomvia*), little auk (*Alle alle*), and common eider (*Somateria mollissima*). In general, organochlorine contamination was moderate, reflecting biomagnification in the food chains. Differences in levels between species are discussed in relation to geographical and ecological aspects.

AIRBORNE CONTAMINANTS AND THEIR IMPACT IN THE CITY OF REYKJAVÍK

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In the capitol of Iceland, Reykjavík, and its neighboring communities live about 146,000 inhabitants, more than 60% of Iceland's total population. The result of this conglomeration of people, traffic, buildings, and industry is a serious disturbance of the sensitive subpolar ecosystem of the area. The natural plant and animal communities have been replaced by anthropogenic urban ecosystems with a different fauna and flora in changed microclimatic conditions. The impact of human activity increasingly endangers air, soil, and water. Since there are no major industrial air polluters and no power stations using fossil fuels, and since houses are heated by clean geothermal energy, motor vehicle traffic is the main source of air pollution in the area of Reykjavík. A high percentage of vehicles (more than 500 per 1,000 inhabitants) and a great road performance cause considerable emissions of air pollutants. These are, however, mostly blown away by the strong prevailing winds (annual mean windspeed more than 6 m/s, only 3% calms). Concentrations of the main air pollutants, nitrogen oxides (NO_x), carbon monoxide (CO) sulfur dioxide (SO_2), and total suspended dust (TSP), have been monitored since 1990 by a mobile measuring station at various locations in Reykjavík. Furthermore, deposition rate data of total dust, anions [e.g., nitrate (NO_3^-), sulfate (SO_4^{2-})] and cations (e.g., heavy metals) were obtained by a network of collectors of dry and wet dust precipitation within the whole city area. These measurements show that the highest levels of air pollutants appear along the roads with the highest traffic volume and also at major crossroads in downtown Reykjavík. Although air pollution is generally at rather low levels and limit values have only rarely been exceeded, pollutants have been found in soil and moss samples. Thus, airborne contaminants affect the distribution, diversity, and vitality of organisms, especially of lichens, in the city of Reykjavík.

A CRITICAL EVALUATION OF NATURALLY GROWING MOSS AS A MONITOR OF ATMOSPHERIC METAL DEPOSITION

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Naturally growing mosses have been used extensively to monitor atmospheric deposition of heavy metals and other trace constituents. In Norway, deposition surveys were carried out on a national scale in 1977, 1985, and 1990, using the feather moss *Hylocomium splendens*. As many as 29 elements were included in the 1990 survey. In this presentation, evidence from this work and other investigations is used as a basis for a critical evaluation of the moss technique. We focus on two aspects: (1) the relative efficiency of the moss as a collection medium for different elements and (2) the contribution to the elemental composition of the moss from sources other than air pollution (e.g., atmospheric transport of marine components, local soil dust, and uptake from soil via higher plants) and subsequent transfer to the moss. Problems associated with the use of mosses as biomonitors in the Arctic will be discussed in particular.

CONTAMINANT CHRONOLOGY OF SOME LAKES IN FINNISH LAPLAND

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Three lakes in northernmost Finland were selected for sediment studies as a part of the Arctic Monitoring and Assessment Programme (AMAP). The lakes were cored in spring 1992 for heavy metal and persistent organic pollutant analyses, as well as for radiometric dating. Anthropogenic signals of heavy metals have been reported from lakes in Lapland, but they usually lack isotope dating. There are no previous data of persistent organic contaminant levels in lake sediments of northern Finland. This study will be carried out according to the guidelines and protocols of the AMAP Freshwater Monitoring and U.S. EPA Arctic Contaminants Research Program (ACRP), and will include metals (e.g., Hg, Cd, Cu, Pb, Zn, Ni, As), PAHs, PCBs, DDT/DDE, HCHs, HCB, etc. Fish from the lakes will also be analyzed for the same contaminants. Preliminary results of the contaminant history will be presented and discussed.

ORGANOCHLORINE RESIDUES IN SEALS FROM DIFFERENT LOCATIONS IN ICELAND COMPARED TO RESIDUES FROM OTHER MARINE REGIONS

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In 1989, seal blubber of harbor seals (*Phoca vitulina*) from southeastern Iceland, as well as grey seals (*Halichoerus grypus*) from western Iceland were analyzed for organochlorine residues such as PCBs, DDT and metabolites, HCH isomers (including the determination of α-HCH enantiomers), HCB, and toxaphene. There were unexpectedly large differences in the residue patterns of chlorinated hydrocarbons between these two groups, e.g., the harbor seal samples from southeastern Iceland showed higher PCB burdens than the grey seal samples from western Iceland. Both spatial (southeastern versus western Iceland) and biological (harbor seals versus grey seals) factors may be taken into account to explain the observed differences. However, evaluation of these data from 1989 could not clarify this distinction. Therefore, in 1992, selected samples from harbor seals as well as from grey seals from the same location in western Iceland were analyzed to determine contamination with chlorinated hydrocarbons. The new data also include results from different tissues (blubber, brain, kidney, liver, and muscle). Finally, 1989 and 1992 data from seals in Iceland will be compared to data derived from seal samples from the Antarctic (Weddell Sea), the Arctic (Spitsbergen), the North Sea, and the Baltic Sea, in order to discuss the organochlorine residues in seals as a global interrelationship.

LEVELS OF THE MAIN GROUPS OF CONTAMINANTS (HEAVY METALS, ORGANOCHLORINES, PAH, PHENOLS, AND RADIONUCLIDES) IN THE BOTTOM SEDIMENTS AND SAMPLES OF BENTHIC ORGANISMS IN THE WATER AREA OF THE WHITE, BARENTS, AND KARA SEAS

Sergey V. Vlasov and S.A.Mel'nikov, Regional Center in Monitoring of the Arctic, Bering Street 38, St. Petersburg 199397, Russia.

The presentation summarizes the data on the levels of organochlorines, PAH, heavy metals, phenols, and pH in bottom sediments and benthos organisms of the White, Barents, and Kara Seas. The available results indicate that of all the seas of the Russian Arctic, the seas of the western sector, especially the White Sea, are subjected to the greatest extent to the effects of regional and local contaminant sources. Contaminants are being accumulated by the benthos organisms and are being stored in bottom sediments in the process of biosedimentation and outflow of solid particles (estuaries and barriers, zones of geochemical barriers).

In spite of existing opinion about the catastrophic radiation situation in the seas of the western sector of the Russian Arctic, the content of gamma-emitting radionuclides over the largest part of the studied water area does not exceed 99 Bk. The content of organic contaminants depends to a great extent on local input sources, as well as on the biological species of the investigated benthos organisms. And the variations of concentrations can reach 1000%. On the whole, the mean content of pollutants in bottom sediments and benthos organisms is lower in seas of lower latitudes. The data presented result from a 4-year cycle of field observations.

ORGANOCHLORINE CONTAMINANTS IN AN ARCTIC ALASKAN LAKE

Rose Wessling-Wilson[1], S. Allen-Gil[1], D. Griffin[1], J. Jenkins[1], and D. Landers[2]

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A wide range of chlorinated organic compounds were measured in lake trout (*Salvelinus namaycush*), grayling (*Thymallus arcticus*), and freshwater snails (*Lymnaea elodes*) from Schrader Lake, a remote lake in Arctic Alaska. Results confirm the long-range transport of several chlorinated pesticides and polychlorinated biphenyls (PCBs). Lake trout muscle samples show concentration ranges (ng/g wet weight) for the following analytes: α-hexachlorocyclohexane (0.16–0.98), Lindane (0.03–0.26), hexachlorobenzene (0.27–2.0), dieldrin (<MDL–1.03), heptachlor epoxide (0.19–0.63), p',p'-DDE (0.8–5.14), and gamma-chlordane (<MDL–0.13). Liver samples for both species of fish reveal contaminants as well. Grayling and snails, both major dietary components for lake trout, have been evaluated for their role in trophic transfer of chlorinated contaminants.

C HUMAN HEALTH ISSUES

Organizer: Gunnar Lundqvist

Purpose: Airborne contaminants, including radionuclides, are known to accumulate in arctic ecosystems. Human exposure to these contaminants is mediated primarily by the bioaccumulation potential of the contaminants and by dietary habits. Indigenous people may be particularly at risk for exposure to contaminants through dietary intake due to their substantial dependence on wild foods. Contaminants may also have indirect effects on humans if they affect the quality or quantity of arctic resources on which indigenous peoples depend. This session will explore the interactions between arctic contaminants and humans, and the possible health effects humans may consequently experience as one of the top predators in the Arctic.

ORAL PRESENTATIONS

1:30 - 3:30	POSTER SESSION I	
3:30 - 4:00	Peter Bjerregaard	Denmark
4:00 - 4:30	Konstantin Gaidul	Russia
4:30 - 4:50	Boris Revich	Russia
4:50 - 5:10	Break	
5:10 - 5:20	Vic Hasselblad	USA
5:20 - 5:40	Pauli Luoma	Finland
5:40 - 6:00	Gunnar Lundqvist	Denmark
6:00 - 6:20		

MORBIDITY AND MORTALITY PATTERNS IN CIRCUMPOLAR PEOPLES

Peter Bjerregaard, Danish Institute for Clinical Epidemiology, Section for Research in Greenland, Svanemøllevej 25, DK-2100 Copenhagen Ø, Denmark

Before World War II, the mortality pattern in the Arctic was characterized by very high mortality due to infectious diseases, in particular tuberculosis, and many deaths due to injuries. Life expectancy was low and chronic diseases such as cancer and heart disease were rare. Improved living conditions and health services have drastically altered the health conditions since then. In Greenland, injuries are still responsible for a large proportion of deaths (27%). The mortality rate from cancer is similar to the rate in western countries. The most important cancers are caused by tobacco (lung cancer) or virus (cervix cancer). Atherosclerosis is less common than in the western world and ischaemic heart disease considerably less prevalent. The disease pattern in northern Canada and Alaska is in many respects similar to the Greenlandic pattern, while the disease pattern in northern Scandinavia is more similar to the European pattern. Only a little is known about the disease patterns of the various population groups in northern Russia. The circumpolar population groups are small and scattered and the burden of pathogenic factors is high. Mortality is well studied, at least in the western hemisphere, but morbidity less well so. In Greenland, interest may be focused on the unique cancer pattern and the alleged high prevalence of congenital heart malformations, but there are only approximately 450 deaths and 1250 births a year to form the basis of a study. The possible impact of environmental contaminants will be difficult to study epidemiologically. Mercury and organochlorines in the traditional diet are presently the most severe environmental threats to human health in the Arctic.

VARIATION OF FOOD CONTAMINANTS INTAKE IN DIFFERENT INUIT COMMUNITIES FROM THE EASTERN CANADIAN ARCTIC AND WESTERN GREENLAND

Hèlène Careau, É. Dewailly, and P. Ayotte, Public Health Centre of Québec, 2050 René Lévesque Blvd. W., Ste-Foy, Québec G1V 2K8, Canada

Wild food consumption is a potential means of exposure in humans to contaminants that bioaccumulate through the food chain. Northern regions are particularly susceptible. Contamination of biota in northern regions has been documented for some time, and the Inuit people depend on wildlife for subsistence. Furthermore, the Inuit play the role of top predator in the Arctic food chain. Although the dietary habits vary according to community and availability of wildlife, a generalized daily wild food intake checklist can be drawn up using various dietary surveys for communities in the eastern Canadian Arctic and western Greenland. Using contamination data of aquatic wildlife of northern Canada and Greenland collected into a database, we evaluate the approximate daily intake of various organochlorines. We also examine geographical variation. An example, using ΣDDT from preliminary results, shows an approximate daily intake from ringed seal blubber (based on diet data from Broughton Island) of 23.5, 11.3, 11.8, and 50.1 μg/day for the respective communities of Upernavik, Arctic, Bay, Inukjuak, and Coral Harbour. Although contamination intake may provide some health concerns, we should not forget the health benefits of a diet based on native foods.

RADIATION HAZARDS TO THE HUMAN POPULATION IN SIBERIA

Konstantin V. Gaidul and V.A. Trufakin, Presidium Siberian Branch of the Russian Academy of Medical Sciences, 2 Timakov Street, Novosibirsk 630117, Russia

Sociological and demographic studies tracking the connection between contamination of the environment and radionuclides, chemical agents, and the physical components of the radiation factor are currently underway in the Altay region. It was revealed that in 40 years, beginning in 1950 (the time of the first nuclear tests), a complex demographic situation has developed in the region, partly due to an increase in environmental stress. Certain indices of population morbidity and mortality are indicators of some sort of increase in the ecological stress throughout the area. From 1950 through 1990, unfavorable trends were revealed in this region in the dynamics of cancer morbidity. They were characterized by a progressive growth trend, close to a linear one (the increase in primary morbidity indices was 4.6 times). The most unfavorable changes in primary morbidity indices were observed for malignant respiratory tumors (an increase of more than 50 times), malignant skin tumors (an increase of 3.4 times), and malignant breast tumors (an increase of 4.0 times). Analysis of indicative morbidity (malignant tumors, thyrotoxicosis, neonatal morbidity) and mortality (from malignant tumors, infant mortality, stillbirth, and congenital anomalies) shows with a high degree of probability that the radiation factor has a place in the contamination of this region.

META-ANALYSIS OF ENVIRONMENTAL HEALTH DATA

Vic Hasselblad, Center for Health Policy Research and Education, Duke University, Durham, North Carolina, USA.

Most airborne contaminants have minimal health effects at typical ambient levels, and this is especially true at arctic contaminant levels. In situations where there are multiple studies of similar health effects, one usually finds that only one or two of the studies show a statistically significant effect. It is only after attempting to quantitatively combine the data that some consistency may emerge. Methods for combining the data from such studies are presented. The methods include combining p-values, combining effect measures using fixed effects models, and combining effect measures using random effects models. Examples of the methods applied to several pollutants, including lead and oxides of nitrogen, will be given. Some discussion of the implications of these findings to contaminant levels found in arctic countries will be presented.

ASSOCIATION OF BLOOD CADMIUM TO PLACE OF RESIDENCE AND HYPERTENSIVE DISEASE IN ARCTIC FINLAND

Pauli Luoma, S. Näyhä, and J. Hassi, Regional Institute of Occupational Health, P.O. Box 451, SF-90101 Oulu, Finland; Department of Public Health Science, University of Oulu, Oulu, Finland

Environmental factors have a great impact on life in the Arctic. The buffer capacity of the soil is low, and environmental pollution may cause acidification and promote the enrichment of toxic compounds in the food chain. Cadmium is a heavy metal that accumulates in the body, particularly in the kidneys. In this investigation, cadmium exposure assessed by blood concentration was evaluated in relation to place of residence and blood pressure in 212 human males (reindeer herders) living in arctic Finland. The exposure to cadmium was related to living area, with the highest in the north-eastern part of the country west of the Kola Peninsula, Russia. Blood pressure increased with increasing concentration of cadmium in the blood, particularly in subjects with diagnosed arterial hypertension, the association being independent of age, body mass index, and smoking and alcohol consumption. Blood cadmium was higher in hypertensive patients than in healthy subjects. The results suggest that environmental exposure to cadmium may be one factor in the rise of blood pressure and development of hypertensive disease.

D. ARCTIC ECOSYSTEM RESPONSES TO ATMOSPHERIC CONTAMINANTS

Organizers: Jesse Ford, Jüri Martin, Reginald Noble

Purpose: Invited overview papers will examine the key characteristics of arctic ecosystems (terrestrial, marine, freshwater) that are most likely to be affected by contaminants of atmospheric origin. The purpose of these overview papers will be to describe where the major sensitivities in arctic ecosystems lie. These papers will include examples of ecological disruption due to atmospheric inputs. Additional invited papers will summarize approaches used to date for studying ecological effects of atmospheric contaminants on terrestrial and aquatic ecosystems. Contributed papers are solicited that (1) describe observed impacts of atmospheric contaminants on arctic ecosystems and (2) describe existing or potential techniques for identifying and tracking change in arctic ecosystems.

ORAL PRESENTATIONS (A.M.)

8:30 - 9:00	David Schindler	Canada
9:00 - 9:30	Vera Alexander	USA
9:30 - 10:00	Jüri Martin/Vladimir Bolshakov	Russia
10:00 - 10:20	Break	
10:20 - 10:40	(Kom Poll. Effects - TBD)	
10:40 - 11:00	Ingibjörg Jónsdóttir	Sweden
11:00 - 11:20	Heather Marshall	Canada
11:20 - 11:40	Margaret Getsen	Russia
11:40 - 12:00	Charles Henny	USA

D. ARCTIC ECOSYSTEM RESPONSES TO ATMOSPHERIC CONTAMINANTS (continued)

ORAL PRESENTATIONS (P.M.)

1:30 - 3:30	POSTER SESSION II	
3:30 - 4:00	Vladislav Alexseyev	Russia
4:00 - 4:30	Mats Olsson	Sweden
4:30 - 5:00	Lyle Lockhart	Canada
5:00 - 5:30	Break	
5.30 - 5:50	Tatjana Moiseenko	Russia
5:50 - 6:10	Thomas Nash	USA
6:10 - 6:30	H. Tommervik	Norway
6:30 - 6:50	Krystyna Grodzinska	Russia

HYDROBIOLOGICAL MONITORING OF FRESHWATER ECOSYSTEMS IN RUSSIA'S ARCTIC

Vladimir A. Abakumov, Global Climate and Ecology Institute, 107258, Glebovskaya 20b, Moscow, Russia

In 1973, we initiated a program of long-term hydrobiological monitoring of rivers and lakes in the Russian Arctic, using a complex of standardized biomonitoring methods adapted to conditions in Arctic regions. Hydrobiological monitoring has been carried out according to this program from 1974 until the present time. The program includes examination of macrozoobenthos, peryphyton, phyto-plankton, and zooplankton. This program includes two subprograms: (1) regular monitoring at the stationary stations and (2) irregular survey investigations. Locations for permanent stations are chosen according to the results of preliminary inventories using express methods. All data on hydrobiological monitoring of rivers and lakes in Russia (including the Arctic region) are obtained by the Joint Scientific Methodological Center, the Department of Freshwater Ecosystems and Paleo-ecology of the Institute of Global Climate and Ecology. The material provided in the current report covers a 20-year monitoring period.

ARCTIC ECOSYSTEM RESPONSES TO ATMOSPHERIC CONTAMINANTS

Vera Alexander, IMS, 200 O'Neill Building, University of Alaska Fairbanks, Fairbanks, Alaska 99775, USA.

The problem of airborne contaminants and their effects on arctic marine systems has not been addressed in a systematic way, although we recognize that there may be significant impacts. The discovery of the phenomenon of arctic haze, for example, has made it very clear that the far north is not immune from industrial contamination. Arctic ecosystems have received attention, however, and, based on programs such as PRO MARE (the Norwegian Research Programme for Marine Arctic Ecology) and ISHTAR (Inner Shelf Transfer and Recycling, a U.S. west arctic study), we can begin to integrate not only the available information on sources and distribution of contaminants, but also their likely effects on the biota. A major problem rests in the fact that arctic marine systems are extremely variable among geographical regions, are extremely patchy even in a single locality, and have very great seasonal oscillations. Timing and location become critical parameters in analyzing impacts, to a greater degree than for systems at lower latitudes. This paper discusses the arctic marine systems with particular emphasis on potential responses to chronic airborne contaminants.

METAL DISTRIBUTION IN CHUKOTKA PENINSULA ARCTIC ECOSYSTEMS

N.V. Alexeeva-Popova, T.I. Igoshina, and I.V. Drosdova, Komarov Botanical Institute, Russian Academy of Sciences, 2 Professor Popov Street, St. Petersburg 197376, Russia

Migration of metals among rocks, soils, and vegetation have been studied in the natural arctic ecosystems of the south, east, and west Chukotka Peninsula and of Wrangel Island. Ecosystems with contrasting geochemical conditions on carbonate, acidic, and ultrabasic rocks, and with different landscape types were examined. Fe, Mn, Cu, Zn, Ni, Cr, Co, Cd, Ca, Mg, and K were detected using atomic absorption spectrometry and spectral emission methods. The chemical composition of 200 vascular plant species belonging to 39 families was studied.

It was revealed that in arctic tundra, not all metal levels in rocks, soils, and plants correlate. We determined the specific correlations of metal concentrations in soils and plants on different rock types. We ascertained the different character of mineral composition variability of arctic plants. This serves as the basis for our recommendations of plant species from some families as indicators of the geochemical situation.

Many species from Asteraceae and Salicaceae families accumulate high concentrations of some metals in different ecological habitats. They show contamination with some rare and heavy metals that are usually accumulated in very low concentrations by biota. The best monitors are the species with high correlation between metal concentrations in the plant tissues and in the habitat (rock).

AIR POLLUTION IMPACT ON ARCTIC AND SUBARCTIC VEGETATION

Vladislav A. Alexeyev, Institute of Forest Research, Krasnoyarsk, Russia

As are other parts of the earth, arctic and subarctic territories are influenced by global, regional, and local air pollution. The greatest load of airborne contaminants is observed in Europe for Kola Peninsula terrestrial ecosystems and in Asia for ecosystems of the Taimyr Peninsula, where large copper-nickel smelters are functioning. In these regions, we studied local and regional deposition of pollutants (mainly sulfates and trace metals), changes in the composition, structure, productivity, and state of forest and tundra vegetation, morphological reactions of plant species and their generative activity, reforestation processes, successions, the element composition of plants and soils, and the biological activity of soils. The findings of long-term studies are as follows: (1) the symptoms of plant damage by air and soil pollutants in arctic and temperate zones are the same, (2) plants weakened by natural stresses have lower thresholds of sensitivity to airborne pollutants, (3) rapid destruction of northern plant communities by pollutants is often connected with a wide distribution of sensitive species (e.g., lichens) and previously weakened plants, (4) the specific structure of far northern forest and tundra ecosystems (in particular, open canopy and/or thin photosynthetic layer) and the severe climate produces some peculiarities in plant damage, namely (a) a large difference in the rate and intensity of damage to upper and lower parts of plants if the green parts are above or under snow in the winter, (b) simultaneous damage of different stories of communities that are above snow cover, (c) increase in the krummholz effect for evergreen coniferous trees. These findings were obtained for conditions of evident airborne contamination. The impact of low-level regional pollutants on arctic and subarctic vegetation is not sufficiently understood. We propose some methods for early diagnosis of the influence of air-borne contaminants on arctic terrestrial ecosystems.

BIOACCUMULATION AND REPRODUCTIVE EFFECTS OF HEAVY METALS IN FRESHWATER ARCTIC ECOSYSTEMS

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Lake trout (*Salvelinus namaycush*) and grayling (*Thymallus arcticus*) are two freshwater species distributed throughout much of the circumpolar arctic. Our experimental design using these species elucidates the bioaccumulation and toxic effects of heavy metals and organochlorines in the arctic, as the species represent two different trophic levels and both are sensitive to the effects of pollutants. Alaska grayling are more sensitive to the effects of heavy metals than other salmonids (*Ecotoxicol. Environ. Safety* 20:325). Lake trout reproduction is impaired at lower concentrations of organochlorines than any other species tested (*Can. J. Fish. Aquat. Sci.* 48:875). As part of the U.S. EPA's Arctic Contaminants Research Program, lake trout and grayling have been sampled from four sites in northern Alaska. Metal concentrations in both species vary among sites, with larger site differences found for lake trout. It is assumed that site-specific effects in lake trout are due to site-specific natural mineral enrichment. Differences in distribution patterns between the two species can be explained by dietary factors. Mercury is the only metal for which concentrations in fish are higher than in sediment. Most of the mercury in muscle tissue is methylated, suggesting that retention of metals is greater when an organic constituent is introduced. At one site, arsenic, cadmium, copper, nickel, lead, and mercury were found in higher concentrations (1–24 times) in lake trout than in grayling. Heavy metal burdens were not correlated with reproductive parameters in lake trout. In male grayling, plasma testosterone was negatively correlated with liver burdens of lead, nickel, and zinc, suggesting the possibility for impaired reproduction.

CHARACTERISTICS OF FIELD VEGETATION LAYERS IN THE KOLA PENINSULA SCOTS PINE FORESTS WITH RESPECT TO AIR POLLUTION

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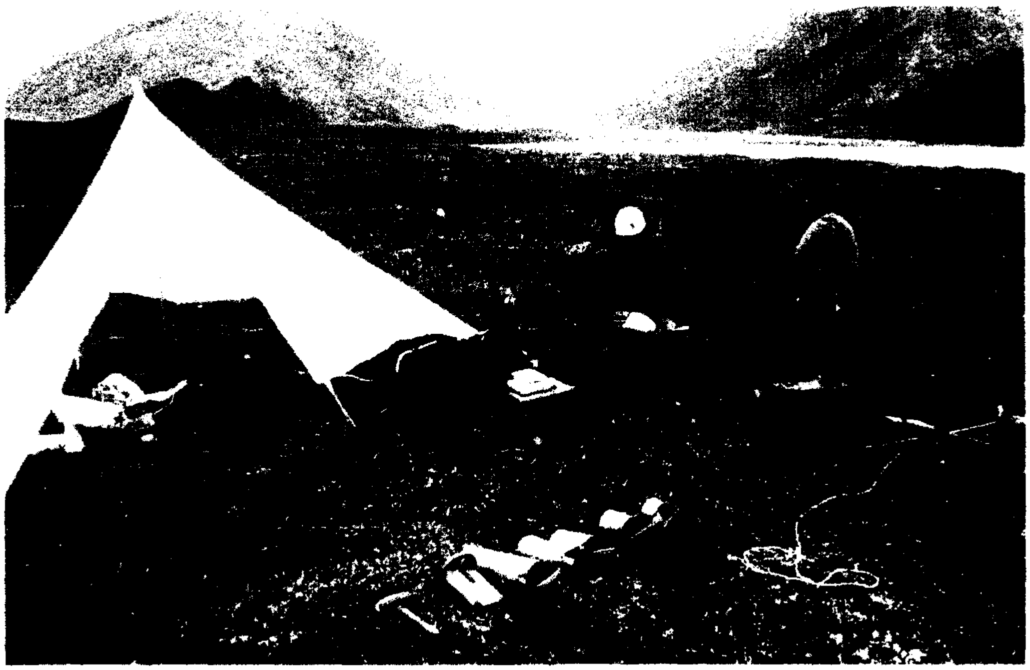
The status of field vegetation layers was studied in pine forests located at varying distances from the Severonikel metallurgical plant. At a distance of 4–12 km from the plant, within the zone of damaged ecosystems, the total coverage of the field layer in Scots pine forests growing on green moss-lichen site types comprised 68% of that in unpolluted regions. Under such conditions, the total projective cover of the field layer in pine forests of the lichen site type was not affected by air pollution. All the basic species forming the field layer on control plots were also present on sample plots located in the polluted regions. Due to air pollution, the relative cover of separate field layer species has undergone essential change. In regions afflicted by high levels of air pollution to the extent that both tree and ground vegetation layers have been almost completely destroyed, the field vegetation layer remains as the only live vegetation component restraining the processes of soil erosion that would otherwise lead to complete degradation of forest ecosystems.



Yuri Shur and Matthew Monetti conduct quantitative soil sampling at an upland site north of Peters Lake, Arctic National Wildlife Refuge, Alaska, U.S.A.

THE INFLUENCE OF NICKEL-COPPER COMBINANT POLLUTION ON REPRODUCTIVE PROPERTIES OF SOME DWARF SHRUB SPECIES OF THE KOLA PENINSULA PINE FORESTS

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The influence of emissions from the Severonikel smelter complex on the reproductive activity of some dwarf shrub species in pine forests of the Kola Peninsula was studied. Investigations were carried out in secondary 45-year pine forests situated at varying distances from the copper-nickel complex. The objectives of the investigation were four species of dwarf shrub: *Vaccinium myrtillus L.*, *V. uliginosum L.*, *V. vitis-idaea L.* and *Empetrum hermaphroditum Hagerup*. The following characteristics were analyzed: the number of seeds in a berry, the dry weight of seeds, and their germination ability. The seeds were germinated under light conditions (1500 lux for 8 hours each day), both without treatment and after gibberelic acid (GA_3) treatment at 20°C and 0–3°C. It was shown that reproductive organs of these plants have differing sensitivities to pollution. Among the species under study, *Empetrum hermaphroditum* was found to be the most sensitive. A reduction of the number of seeds in a berry, as well as a decrease in germination ability, was observed. All species of Vaccinium are markedly less sensitive than *Empetrum hermaphroditum*.

COENOTIC ROLE OF BETULA PUBESCENS UNDER AIR POLLUTION IMPACT

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In the formation of northern Lapland forests, *Betula pubescens* plays a great part. The phytocoenotic role of birch increases strongly in stands located at a distance of 20 km from the Severonikel factory, whose annual emission reaches $25 \cdot 10^4$ tons of SO_2 (Norin, Yarmishko, 1990). It was determined that the impact of *B. pubescens* on lower canopies in the zone of forest damage (zone names follow V. Alexeev and V. Yarmishko, 1985), is revealed at a distance of 1.4–1.6 m from the tree stem, which is equal to the radius of undercrown space. Round birch tree communities with a dominance of *Vaccinium vitis-idaea*, *Empetrum hermaphroditum*, or *Arctostaphylos uva-ursi* are usually formed, strongly differing from intercrown communities. In the zone of complete degradation (3–5 km from the factory), only separate, strongly depressed birch and pines manage to survive, but here the influence of *B. pubescens* on plants of lower canopies is stronger, having formed under trees with low crowns in closed communities with 10–15% of coverage and the same set of species as in the damage zone. Quantitative evaluation of the edificator impact of birch and pine, following the Kotov (1982) method in Maslov's (1990) modification (for heterogeneous) in composition stands, shows stronger phytocoenotic impact of birch ($\eta^2 = 0.54$) in comparison with pine ($\eta^2 = 0.41$). Since *B. pubescens* endures the prolonged impact of high concentrations of SO_2 in atmosphere sufficiently well (Schubert 1985), the edificatory impact of birch on vegetation of lower canopies is stronger here than in *Pinus sylvestris*.

ION BALANCE STUDIES IN FINNISH LAPLAND

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The effects of atmospheric pollutants (SO_2, Cu, Ni) from nickel and copper smelters in the Kola Peninsula, Russia, on forest soils in Finnish Lapland are being investigated using an ion-balance approach. Precipitation (water and snow) and percolation water samples have been collected from 25 ion balance monitoring plots in Finnish Lapland, Norway, and Russia since 1989. Preliminary results indicate that forest soils in Finnish Lapland are not subjected to an appreciable acid load because of the relative proximity of the emission sources (slow conversion of sulfur dioxide to sulfuric acid) and the prevailing wind direction (N-S). The studies on stand throughfall indicate that organic matter leaching naturally from the crown canopy explains much of the increase in acidity found under coniferous species in the region. Nutrient cycling within the stand also explains much of the increase in S, Ca, Mg, K, etc., in stand throughfall. Organic matter dissolved in the percolation soil water in these arctic soils plays a dominant role in binding aluminum and in regulating soil water pH in the surface layers. The relatively low precipitation, coupled with the long period when the ground is frozen, suggests that the leaching of soil nutrients is not like to be a major problem even at higher acid load levels.

USE OF THE POPULATION APPROACH IN STUDYING AIR POLLUTION EFFECTS ON WILD BERRIES

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The perspectives of using population biology methods in the study of air pollution effects on plants whose populations are complex polycentric systems will be shown. Widely spread wild berries (*Vaccinium myrtillus L., V. uliginosum L.*, and *V. vitis-idaea L.*) are among these. The importance of studying these plants comes from their use as food and medicinal products. The approaches offered have been tested for the estimation of the effects of airborne contaminants on bilberry populations growing in similar types of pine and fir forests of the Kola Peninsula at different distances from the Severonikel smelter complex. The study of the population structure is based on an analysis of their heterogeneity level and the qualitative and quantitative variety of their elements. For determining the level of diversity, a complex of morphometric parameters was applied. A selection of the most informative qualities was performed. It appears that general indices of partial shrubs of bilberry have undergone the least changes. The maximal response is characteristic of functionally significant indices determining the growth process in plants. The level and structure of morphometric correlations of qualities were analyzed. The ecological, morphological, and ontogenic plasticity of a species provides a possibility for changing the density and the age structure of populations according to the conditions of growth. The effect of industrial air pollution results in transformation on both individual and population levels. Changes in basic population characteristics aim at the maintenance of plant mass. The conclusion about the relative resistance of bilberry to the effects of air pollution is confirmed.

IMPACT OF AIR POLLUTION ON TUNDRA AND FOREST ECOSYSTEMS OF THE TAIMYR PENINSULA

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The goal of this research is to estimate the impact of air pollution on the status of tundra and especially of forest ecosystems of the Taimyr Peninsula at the altitudinal and northern limits of their distribution. Long-term studies revealed peculiarities in ecological conduction in the background area located 100 km east of the Norilsk copper-nickel complex. The vegetation of altitudinal belts was investigated and an analysis of floristic complexes of mosses, lichens, fungi, and higher plants was performed. The altitudinal profile traced the changes of annual productivity and phytomass reserves, and their transformation and fractional composition. Ecosystem changes that occurred in areas affected by air pollution tended to copy changes of vegetation in the altitudinal profile of the background area. The changes that occurred in the degradation of forest ecosystems into industrial waste lands were different from the natural changes in vegetation along altitudinal belts. The data obtained favor a decrease in the radial increment of arboreal species approaching the complex. Also, heavy metal contaminants negatively influence the development and distribution of root systems. During recent years, intensification of the damage of apparent assimilation has been observed.

BLACK CARBON IN THE HIGH ARCTIC ENVIRONMENT

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Spatial and temporal distribution of black carbon particles in the High Arctic of Canada, as documented by analysis of lake sediment, snow, and plant samples, offers physical evidence of the transport and deposition of anthropogenic combustion emissions. While it is well understood that black carbon is an important factor in consideration of climatic influences of anthropogenic activities, its role in the study of arctic contaminants is relatively unexplored. This study looks at three applications of research on black carbon particles to the issue of arctic contaminants. The association of temporal black carbon particle distributions with some known distributions of contaminants of interest in arctic ecosystems may enhance our understanding of the development of delivery systems for contaminants. The spatial comparisons of black carbon distributions with exotic pollen present may contribute to identification of source areas. The comparisons of temporal changes in black carbon distributions with known distributions of diatoms and other microflora suggest possible ecological effects.

PALEOLIMNOLOGICAL EVIDENCE OF RECENT ENVIRONMENTAL CHANGES IN HIGH ARCTIC TUNDRA ECOSYSTEMS

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This study examines the diatom stratigraphic profiles from several ponds located on Cape Herschel (78°37'N, 74°43'W), eastcentral Ellesmere Island, Canada. This region is unique for high arctic studies, as four years of baseline physical, chemical, and biological data are now available for the numerous (+40) ponds located on this rugged peninsula. Moreover, previous researchers completed reconnaissance surveys of the Cape and noted measurable concentrations of several airborne contaminants. Cores from the frozen sediments of these ponds were retrieved using a modified Livingstone piston corer. Radiocarbon dating of the sediment cores (collected by Dr. W. Blake, Jr., Geological Survey of Canada) indicated that these ponds were formed several thousand years ago. Paleolimnological analyses of the fossil diatom assemblages revealed that the pond environments were relatively stable over all but the last century or so of pond ontogeny, when diatom assemblages changed markedly. At the present time, we cannot determine what caused these shifts in diatom species composition, except to speculate that they were related to airborne contaminants or recent climatic changes. What is clear, however, is that these arctic ponds have experienced unparalleled environmental changes over the last century.

THE REACTION OF ARCTIC PLANTS TO ATMOSPHERIC AEROSOL POLLUTION

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Our investigations were conducted in 1900–1992 on Wrangel Island (clean zone) and the Kola Peninsula (Perchenga, polluted zone). The results give us the background to speak decisively about actions of aerosol pollution factors related to natural phytocoenosis. On Wrangel Island, air pollution by aerosol is insignificant, due to the absence of a constant source of tropospheric pollution, and plant biocoenosis is not damaged. But on the Kola Peninsula, especially in districts subjected to extreme and constant aerosol pollution, breaches are observed in plant biocoenosis in connection with changes in the dominance and disappearance of separate varieties as a consequence of, for example, an increase in radiation (red spectrum) or a breach of temperature regime (increase or decrease, depending on the quality of aerosol). Therefore, we can talk about the negative influence of aerosol pollution on arctic species that are very sensitive to alteration of the microclimate and biocoenosis on the whole.

DELINEATING ECOREGIONS OF NORTHERN CIRCUMPOLAR COUNTRIES

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6 Hughes STX Corp., EROS Alaska Field Office, 4230 University Drive, Rm. 230, Anchorage, Alaska 99508-4664, USA. Work performed under U.S. Geological Survey contract 1434-92-C-40004.

Ecological regions of northern circumpolar countries are being mapped to provide a framework for integrating scientific research and monitoring programs across international boundaries. This geographic framework will be useful for (1) providing a basis for designing statistical analyses (for post-stratification of existing sample sites or prestratification and density determination of new sample sites), (2) locating regionally representative sample sites for assessment and monitoring programs, and (3) extrapolating data collected from local study sites to larger areas. The project encompasses parts of Canada, Denmark (Greenland), Finland, Iceland, Norway, Russia, Sweden, and the United States (Alaska). This effort represents a collaboration of scientists from a number of agencies, including the U.S. Environmental Protection Agency, the U.S. Geological Survey, Environment Canada, the United Nations Environment Programme's Global Resource Information Database at Arendal, Norway, and Moscow State University. The methodology for this project is a qualitative assessment of coincident patterns in dominant soils, geology, vegetation, climate, and land cover characteristics of arctic and subarctic systems. Such a method has already been used to delineate ecoregions for the conterminous United States, Alaska, and Canada. Because of discontinuities in environmental information and classification systems across international boundaries, remotely sensed data from the Advanced Very High Resolution Radiometer (AVHRR) sensors are being incorporated to provide a source of current, spatially continuous information across the entire northern circumpolar area.

AN ECOPHYSIOLOGICAL PERSPECTIVE ON A SYSTEM FOR MONITORING ARCTIC AIRBORNE CONTAMINANTS

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The extent to which contaminants affect ecosystems depends mainly on the physiological response of species and individual organisms—their heredity, age, and natural initial resistance. The vital and most sensitive processes (photosynthesis, respiration) offer insight into the way plants cope with their substantially transformed environment. We emphasize that such criteria provide an opportunity to recognize early stages of plant damage before externally visible symptoms can be seen. Additional factors (accumulation of some anions and cations, transformation of light and gases regime) substantially influence the coefficients of photosynthesis, respiration and growth, and carbon balance.

We propose a uniform methodological approach that allows proper selection of samples, objectives, and parameters that should be considered. This challenge exists even in field studies of unpolluted ecosystems and increases drastically when contamination is added. To overcome the difficulties, we propose: (1) to select parameters considering their informational capacity for estimating the "normal" response of a plant and the deviations caused by pollution, (2) to find ways of gathering adequate information regarding diurnal and seasonal variability at every phase of onthogenesis, and (3) to find adequate information about seasonal parameters in connection with growth longevity. The concept of the ecophysiological species passport (ESP) has been developed as a key tool for estimating the "normal" response of species. The ESP for 159 species studied on Wrangel Island, in the polar Urals, and on the Kola Peninsula and Taimyr provides additional information on arctic flora of the USSR and background information on biological monitoring.

INDICATION OF MODERN ECOSYSTEM QUALITY IN EAST EUROPEAN ARCTIC UNDER THE ANTHROPOGENIC INFLUENCE OF ALGAE

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Algae constitute one of the most important components of subarctic terrestrial and freshwater ecosystems in east European tundras. Long-term study of algal flora in the territory of the Vorkuta industrial complex indicated diverse assemblages of 500 species, of which 344 were diatoms. Little is known about the response of algal communities to environmental changes in subarctic regions. We used different groups of algae, especially diatoms, as bioindicators to analyze the transformation of composition and structure of communities under anthropogenic stress. Ecosystems have been contaminated with industrial air pollution and with pollutants from effluent waters of coal mines, population conglomerations, and agriculture. The results indicate that pollution affects the structure and functions of terrestrial and freshwater ecosystems. There are changes in species diversity and taxonomy, and in the ecological and functional structure of algal assemblages. Algae should be an important part of the monitoring program for the far north, since they are considered to be especially sensitive to human activity.

CHARACTERISTICS OF EPIPHYTIC LICHEN COVER IN THE KOLA PENINSULA SCOTS PINE FORESTS WITH RESPECT TO AIR POLLUTION (SEVERONIKEL COMPLEX)

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Results from a study of the epiphytic lichen cover of pine trunks in different habitats in background and in polluted regions were analyzed. The total number of descriptions is 10,000, gathered at 35 permanent sample plots, and organized into groups at distances of 8, 15, 30, and 55–80 km from the Severonikel complex. Using nonparametric methods (Kolmogorov-Smirnov test), it was possible to classify projective cover distributions of lichens at separate sample plots. This classification characterizes different types of epiphytic lichen cover productivity and is similar to the scale of forest plant botany classes. The stationary state of epiphytic lichen cover was described on the basis of frequency of occurrence of productivity types. Changes in the stationary state of epiphytic lichen cover due to airborne contaminants were analyzed.

QUANTITATIVE ESTIMATES OF MOSS-LICHEN COVER DISTURBANCE IN POLLUTED AND NONPOLLUTED SCOTS PINE FORESTS IN THE KOLA PENINSULA

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The total projective cover of mosses and lichens and the relative cover of separate species and their heights in dry pine forests with different ages of last disturbance (fire) were analyzed in nonpolluted and polluted regions. The total number of descriptions is 3,000 at 35 permanent sample plots, organized into groups at distances of 8, 15, 30, and 55–80 km from the Severonikel complex. The age (time) of last disturbance proved to be the most important characteristic that determines the state of moss-lichen cover in nonpolluted regions. The state of moss-lichen cover experiencing different levels of airborne contaminants was analyzed.

ARE MOSSES AND LICHENS INDICATORS OF ENVIRONMENTAL CONTAMINATION IN THE ARCTIC?

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Several moss and lichen species were employed to assess the degree of environmental pollution by Cd, Pb, Ni, Cu, Zn, and S in a large area of southern Spitsbergen and in the area closely surrounding the Polish Polar Station in the Hornsund region. High concentrations of heavy metals and sulfur in selected moss and lichen species were found, along with differences in concentrations of those elements between species and sites. Results of the studies presented showed that the level of cations and sulfur content in mosses and lichens depends on the geological and climatological conditions specific to the arctic region and on the long-range and local transport of pollutants. Thus, mosses and lichens should be used with caution as indicators of air pollution in southern Spitsbergen.

POSSIBLE CHANGES IN BIOLOGICALLY ACTIVE ULTRAVIOLET RADIATION IN THE ARCTIC IN SUMMERTIME DUE TO INTERANNUAL TOTAL OZONE VARIABILITY

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Biologically active UV-B radiation (280–320 nm spectral band) reaching the biosphere is controlled mainly by ozone absorption. Data for total ozone measurements collected by the world ozone measuring network since 1972 have been analyzed to study ozone interannual variability and estimate its possible effect on the UV-B dose received by the Arctic biosphere. Possible interannual changes in UV-B dose received by DNA, the main genetic material, are calculated for different summer months, due to overall interannual ozone variability, as well as to the quasi-biennial oscillation (QBO) in total ozone. In general, the largest interannual variations in UV-B dose potentially occur in the vast region of the Russian Arctic, while the potential variations in the Canadian Arctic are smallest. The overall variations in UV-B dose received by DNA can exceed 25% (at 26-criterion) in the Taimyr and Severnaya Zemlya in June and July and can exceed 30% in the Laptev Sea in August. In the European sector of the Arctic, the possible variations are greater than 10% and can exceed 15% in the north Norwegian Sea in July and 20% in Spitsbergen in August. The possible overall variations in the Canadian Arctic and Alaska are about 10% or less; however, they can reach 15% in Alaska in August. The total ozone QBO can also cause essential and statistically predicted changes in UV-B radiation. In general, the UV-B dose received by DNA is found to be greater in the Arctic during the west phase of the QBO of the equatorial stratospheric wind at 50 mb level than during the east phase. The difference can reach or exceed 15%, relative to the mean value, in Taimyr in June and in Severnaya Zemlya in July and August. In northern Europe and Iceland, the difference can reach 10% in August. In the Canadian Arctic, the QBO-related effect is small. In Alaska, the appropriate difference in UV-B dose has an opposite sign in August, exceeding 5% in magnitude.

MONITORING OF FOREST ECOSYSTEMS OF RUSSIAN SUBARCTIC SUBJECT TO INDUSTRIAL IMPACT: TASKS AND PURPOSES

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Since 1986, the Institute of Global Climate and Ecology has been monitoring environmental pollution and estimating the status of forest ecosystems located in polluted areas. A monitoring network, Monitoring the Impact of Environmental Pollution and the Status of Vegetation, was organized by the end of 1990. The network includes some stations located in the Russian subarctic (Kola Peninsula and Norilsk industrial region, Taimyr Peninsula). In the current report, control of the original state of the forest and methods used to detect industrial pollution, applied over the stations of the Network, are discussed and aanalyzed in comparison with European methodology. Some results of the study of pollution levels related to forest health in the vicinity of large enterprises are presented.

CADMIUM AND SEA DUCKS IN ALASKA AND PERHAPS THE CIRCUMPOLAR REGION

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Surf scoters, white-winged scoters, and black scoters nest inland at freshwater lakes and ponds in Alaska and northern Canada, and winter farther south in coastal zones. Surf scoters wintering in Oregon and Washington contained elevated concentrations of cadmium, and body weight was negatively correlated with cadmium. Independent of these findings were observations of all three species dying in southeastern Alaska during the August wing molt (a stressful period in the life cycle); some of the dead and moribund scoters contained cadmium concentrations (>50 to 300 μg/g dry wt) that were greater than those from the Oregon-Washington coast. Blood samples from moribund scoters provided evidence of renal disfunction, and census data indicated reduced scoter populations. In addition to benthic-feeding scoters, the benthic-feeding spectacled eider in Alaska was recently classified as an endangered species by the U.S. Fish and Wildlife Service. Its population declined from about 60,000 to 10,000 between 1955 and 1989, and elevated cadmium concentrations were found in kidneys of several confiscated eiders. We will outline a new research effort now underway to determine if cadmium (perhaps from airborne sources) is adversely affecting scoter and eider populations in Alaska. Cadmium concentrations in other circumpolar birds also will be reviewed.

The Cessna 180 aircraft in which Glenn Shaw, Andy Borys and Ken Rahn collected arctic haze in 1972. It was found that the haze consisted of a combination of desert dust from the Gobi Desert and industrial air pollutants.

ORGANOCHLORINE INDUSTRIAL COMPOUNDS AND PESTICIDES IN FRESHWATER ARCTIC CHAR FROM KASEGALIK LAKE, BELCHER ISLANDS, NORTHWEST TERRITORIES, CANADA

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Arctic char (*Salvelinus alpinus*) were collected from Kasegalik Lake on the Belcher Islands in Hudson Bay and analyzed for up to 121 PCB congeners, hexachlorobenzene, dieldrin, α- and γ-hexachlorocyclohexane (HCH), and p,p'- isomers of DDT, DDD, and DDE. Fish ages were determined by enumeration of annuli on sectioned sagittal otoliths. The Islands are home to approximately 500 Inuit who rely on arctic char from Kasegalik as a primary food source. Since there are no industrial or agricultural activities on the Islands, presence of these target compounds is assumed to result from atmospheric transport to the region. Highest PCB concentrations by congener are generally less than 10 ng/g (wet mass), and are found in 10 congeners (105+153+132, 163+138, 170+190, 180, and 187+182), which together comprise about 35–50% of total PCB (less than 60 ng/g in most samples). This congener distribution pattern is similar to that found in fish from areas outside the Arctic; several of the more toxic coplanar PCBs are included. HCB is found in all samples at levels less than 1 ng/g. Dieldrin, DDD, and DDT are found in few samples and in very low concentrations. α-HCH concentration is variable, but is generally 10 times greater than the γ-HCH isomer. Amounts of DDE also vary, and are usually the most concentrated of any pesticide observed. Because of the variability of fish size (mass and length) with age, older fish do not always show highest concentrations of target analytes. Although the concentrations of these analytes do not necessarily suggest a harmful effect to humans consuming fish, the amounts are high enough to suggest careful observation of concentrations of potentially harmful substances in food sources.

An Arctic fox.

EARLY WARNING SYSTEM FOR TERRESTRIAL BIOTA INFLUENCED BY ATMOSPHERIC POLLUTION

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Epiphytic lichens are very sensitive to atmospheric pollutants such as sulfur dioxide and nitrogen oxides. They also accumulate heavy metals. Thus they have been widely used as air pollution indicators in urban areas and near emission sources for more than 100 years. We analyzed the capacity of various groups of organisms to serve as indicators of a trend of large-scale air pollution far from emission sources. Epiphytic lichens were shown to be the most suitable subject for this; they also serve as a priority subject for an early warning monitoring system for terrestrial biota influenced by air pollution. Since the late 1970s, field surveys of epiphytic lichens in biosphere reserves and other protected areas located far from emission sources have been carried out on a systematic basis in Russia. The goal of this survey is to obtain quantitative information on epiphytic lichens suitable for trend detection. We developed a special methodology for field observation to reach this goal. The integrated index (II) of the state of epiphytic lichens under air pollution conditions was suggested. This index is based on the cover of epiphytic lichens of different species obtained from field surveys and on estimates of sensitivity of epiphytic lichens taken from literature or resulting from mathematical modelling. The II is the best index from the class of linear indices. The II has the highest resolution of epiphytic lichens trend induced by air pollution in respect to their natural variability and measurement errors. At present, more than 30 nature reserves in the northern hemisphere have been explored. The list includes Kandalaksha Reserve (66°N, Kola Peninsula), Pechora-Ilych Biosphere Reserve (62°N, Pechora), and the Sandnaeset Monitoring Area (64°N, Jamtland County, Sweden). Epiphytic lichens are being assessed in these areas (and in others as well). These estimates may serve as a basis for an early warning monitoring system of terrestrial biota in the northern hemisphere.

THE EFFECTS OF INCREASED NITROGEN DEPOSITION ON ARCTIC PLANT COMMUNITIES

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Arctic plants in general are adapted to the low availability of nutrients, which is usually a limiting factor for plant growth and development in the Arctic. Arctic plant species and communities may, therefore, be sensitive to even small changes in the nutrient input, such as increased nitrogen deposition, which is a major environmental problem in the industrialized countries. Although nitrogen deposition has not increased as drastically in the Arctic as it has elsewhere, arctic areas have not been left unaffected. Chemical analysis of ice cores from the Greenland glacier indicate a twofold increase in the N deposition there during the last 100 years. Plant communities in the Arctic are often simple in structure, and cryptogams, such as mosses, are usually abundant. For example, *Racomitrium* moss heath with *Carex bigelowii* is a widespread vegetation type in Iceland and elsewhere in the maritime parts of the Arctic. Such simple vegetation types are useful models for studying the responses of major growth forms, such as the mosses and the clonal graminoid, to increased N deposition. The two growth forms are adapted to take up nitrogen from different sources. The moss is effective at immobilizing all atmospheric nitrogen, even at increased rates, while the clonal graminoid depends on nitrogen released through decomposition and mineralization in the soil for its nitrogen acquisition. Clearly, any extra input of nitrogen into the system has the potential to unbalance the community, because of the difference in abilities of the two life forms to acquire the resource. This paper discusses an experiment in which ^{15}N was applied in different ways to *Racomitrium* moss heath.

ENVIRONMENTAL RESEARCH PROGRAMS IN THE GEOLOGICAL SURVEY OF FINLAND (GSF), REGIONAL OFFICE OF NORTH FINLAND

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Several interdisciplinary environmental research programs are being carried out by the GSF in northern Finland. Essential topics are the sensitivity of soils to acidification and the extent and effects of the well-known S, Ni, and Cu emissions from the smelting plants of Severonikel and Monchegorsk in the Kola Peninsula. The present stage of the research programs is as follows.

Acidified and acidifying lakes are found in large areas of northern Finland. The sensitivity of mineral soils to acidification varies considerably by area due to geological characteristics and harsh climate. The sensitivity of soils and lakes to acidification and soil/lake interactions were determined by analyzing 26,856 till samples and 1007 lake water samples from northern Finland. The results indicate that the sensitivity and trend to acidification of a lake depends strongly on the solubility and weathering of minerals in soils in the catchment area. In addition, the size of the catchment area is important. In the northeastern part of Lapland, high sulfur deposition is clearly correlated with acidified clear water lakes. In the southern part of Lapland, organic acidity derived from peat lands plays a big role in the acidity of humic lakes.

Regional sampling of terrestrial mosses (*Hylocomium splendens*) with a density of one sampling site per 60 km^2 was carried out with the Nordkalott Project in 1982–83 in eastern Finnish Lapland. The results revealed anomalous patterns of Ni and Cu in northeastern Lapland as a consequence of emissions of these elements from the smelters of the Severonikel area. Sampling was repeated in 1990 with a density of one sampling site per 300 km^2. The results of both sampling methods were comparable, indicating that the moss is a good bioindicator for airborne deposition, and the repeated sampling gives a good basis for estimating trends in airborne deposition. Several additional sources of anthropogenic pollution were identified related to mining and metal processing and urban activity. The background levels of some elements are decreasing from south to north, revealing long-range transport. The concentration levels of Pb decreased by about 50% during the two sampling periods. The results were used to distinguish natural variations of heavy metals and sulfur from anthropogenic effects. In addition, mosses have been used to study urban emission. In the vicinity of heavy metal emission sources in Kola, the extent and level of airborne pollution has been studied using humus and snowpack samples. The results have been compared with the results of moss samples to estimate the heavy metal and sulfur deposition in northern Finland.

RESPONSE OF SMALL CATCHMENTS IN LAPLAND TO CHANGES IN ACIDIFYING DEPOSITION

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The SMART (Simulation Model for Acidification's Regional Trends) model has been developed to estimate long-term chemical changes in soil, soil water, and runoff water in response to changes in atmospheric deposition. Its major outputs include base saturation, pH and the molar Al/Ca ratio for soils, and major cations and anions for soil and runoff water. The model structure is based on the anion mobility concept by incorporating the charge balance principle. SMART consists of a set of mass balance equations that describe the soil input-output relationships for the cations (Al^{3+}, Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+) and strong acid anions (SO_4^{2-}, NO_3^-, Cl^-), and a set of equilibrium equations that describe the equilibrium soil processes. The soil solution chemistry depends solely on the net element input from the atmosphere and the geochemical interactions (weathering and cation exchange) in the soil. The various exchange reactions are described by Gaines-Thomas equations. The model has recently been enhanced by the inclusion of descriptions of (1) sulfate adsorption, (2) organic anions, (3) denitrification, and (4) N-immobilization. The influence of the nutrient cycle (foliar exudation, foliar uptake, litterfall, mineralization, and root uptake) is not considered. The water is stationary on the time step selected for the application. The reason for the use of long time steps is the focus on long-term effects. SMART is applied to the Christmas Lakes, a chain of three small oligotrophic catchments in northeast subarctic Finnish Lapland (69°25'N, 29°11'E), located a few km from the border to Norway and 40 km from the Severonikel smelter in Russia, a major source of sulfur emissions. The Christmas Lakes are less than 60 ha in size, have clear water, and are low in base cations and alkalinity. At present, the lakes are not very acidic, the pH being around 6.5 in the fall. The SMART model is calibrated to present soil and water quality data, using best estimates for historical (1850–1990) deposition patterns. With the calibrated model, the chemical responses of the three catchments to different future acidifying deposition scenarios are analyzed and discussed.

THE STATUS OF RUSSIAN SUBARCTIC FORESTS AFFECTED BY EMISSIONS FROM NONFERROUS METALLURGY ENTERPRISES

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For some time, forests in some regions of the Russian subarctic have been suffering from environmental pollution caused by emissions from nonferrous metallurgy enterprises. Long-term investigations have been conducted by the Institute of Global Climate and Ecology in the areas of industrial impact, located in the territory of the Kola Peninsula and the Norilsk region. The objective of the studies was to accurately estimate forest status at different levels of environmental pollution. The areas of forest damage, the results of the influence of air contaminants, were also determined. This report generalizes the information from studies of the stands' response to pollution stress and suggests some methodological approaches to solve the problem of setting critical loads values for the northern forest ecosystems.

ESTIMATION OF THE IMPACT OF LIQUID AND SOLID ROCKET FUEL AND PRODUCTS OF ITS BURNING UPON ECOSYSTEMS OF THE EUROPEAN NORTH

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Qualitative and quantitative estimation of the impact of products of rocket fuel burning on ecosystems of taiga, forested tundra, and tundra in European Russia and western Siberia is discussed. To assess the degree of damage to ecosystems, we used a complex index, including biomass, specific variation change, and integrity of vegetation and soil cover. On the basis of data on the influence of the components of rocket fuel and the products of its burning, we propose a mathematical model offering the possibility of forecasting ecosystem status and the processes of reconstruction (or degradation). These studies are the first to be conducted in Russian territory.

THE RESPONSE OF TUNDRA VEGETATION TO OXIDES OF NITROGEN

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The development of oil resources on the North Slope of Alaska has produced concern over potential environmental impacts. In 1989, a comprehensive program of field and laboratory studies was initiated to assess the effects of air quality on the structure and function of tundra vegetation communities at Prudhoe Bay. Research in 1989, 1990, and 1992 focused on field studies at Prudhoe Bay. In 1991, the effects of nitrogen dioxide on the physiology of arctic willow (*Salix arctica*) were assessed in controlled pollutant exposures in the laboratory.

The field research has not detected any deleterious impacts of air quality on tundra vegetation at Prudhoe Bay. Ambient concentrations of ozone, oxides of nitrogen, and sulfur dioxide were below the levels generally considered to be harmful to plants. Three years of monitoring vascular and lichen communities along a dispersion gradient of oxides of nitrogen have revealed no changes in species composition that could be related to differences in air quality. In addition, no symptoms similar to those caused by air pollutants were observed on any of the plants. Elevated levels of foliar nitrogen were found in arctic willow in the vicinity of a major source; possible physiological effects of the added nitrogen are being assessed. Responses of arctic willow to controlled laboratory exposures with oxides of nitrogen are uncertain at present. Initial exposures were conducted with plants that were not physiologically stable; arctic willow will have to be held for one year to allow its establishment prior to use in exposure studies.

Definitive evaluation of possible pollutant-induced effects on tundra communities at Prudhoe Bay will require long-term assessment. The current studies in the field are best characterized as: (1) performing preliminary evaluations of possible effects of air quality, and (2) establishing a baseline for future assessments. Thus far, the field research has not detected any deleterious impacts of air quality on tundra vegetation. It is essential, however, to acknowledge the preliminary nature of these evaluations. The field studies are also providing insight into the status and annual variation in the plant communities. Recognition of the magnitude of this inherent change will serve to define the limits beyond which air quality will have to alter the tundra communities for effects to be recognized.

THE INFLUENCE OF GLOBAL CLIMATE CHANGES ON CARBON DIOXIDE UPTAKE BY RUSSIAN SUBARCTIC FORESTS

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The forests of the Russian subarctic zone occupy a large territory in which significant climate changes are expected. These forests may play an important role in the uptake of CO_2 from the atmosphere and the mitigation of global warming. Measurements of the growth of radial trees in warm and cold years in different climatic conditions of eastern Siberia were carried out. Estimates indicated that in the northern Taiga, the growth rate would increase by 15% for 1° of warming; in the coldest conditions on the forests' border, the growth rate would increase by 25% for 1° of warming. A model of carbon dynamics (in wood, green biomass, litter, and humus) under warming, CO_2 increases, and precipitation changes was developed. The subtundra, light, and northern taiga of five Russian regions from Finland to the Far East were studied as the model's blocks. The calculated additional CO_2 uptake caused by climate factors was equal to 50 mln tC/yr. By 2010 and 2030, uptake will make up 75–100 and 100–200 mln tC/yr, respectively, according to different scenarios that are compatible with current anthropogenic emissions in Russia of 650 mln tC/yr. The additional effect of forest expansion to the north in the last 30–40 years is estimated on the basis of primary data from the forest surveys. The expansion currently can cause CO_2 uptake equal to 10–40 mln tC/yr. The possible simultaneous influences of great sources of atmospheric pollutants and climate changes in the Russian subarctic forests are discussed.

CHLOROPHYLL CONTENT AS AN INDICATOR OF AIR POLLUTION

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The maximum content of chlorophyll in fresh leaf matter is a hereditary value, therefore it may be a characteristic of the species. We used chlorophyll content to investigate which species may be indicative of the extent of pollution. The test areas were located at different distances from the Monchegorsk group of mines—Severonikel in the coniferous forest and the pure ones in Puncha. The pollutants consist mainly of sulfur dioxide and a number of heavy metals. The content of chlorophyll in the leaves of the evergreen and deciduous plants was investigated. Four hundred samples were analyzed. The data obtained allowed us to come to the following conclusions:

1. The responses of the species to the pollutants were different.
   a. A small concentration of the contaminants was enough to decrease chlorophyll (mainly chlorophyll-*a*) in the leaves of such species as *Rubus chamaemorus*, *Vaccinium myrtillus*, and *V. vitis idaea*. Higher concentrations did not have an additional effect.
   b. The two species *Vaccinium uliginosum* and *Arctostaphyluva ursi* were rather stable, but a decrease in chlorophyll was proportional to the concentration of pollutants. The correlation between a decrease of the pigment and the quantity of heavy metals in leaves was rather high (r=0.93) (Lyangusova, 1988).
2. *Empetrum hermaphroditum* was the most indicative species. In spite of great accumulation of heavy metals in leaves and the sensitivity of the pigment system, it is widely distributed, even in highly polluted areas.
3. In spite of the presence of sulfur dioxide in the air, pheophytinization of chlorophyll did not take place.

REACTION OF THE LEAF CHLORENCHYMA FROM KOLA PENINSULA PLANTS TO THE EFFECTS OF THE COPPER-NICKEL PLANT

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The effects of industrial atmospheric pollutants on the chlorenchyma cell structure of scots pine needles and leaves from bushes of red bilberry, great bilberry, and bilberry were studied. Our investigations were carried out in 1988–1991 on the Kola Peninsula in the region of the Severonikel smelter, where the dominating gaseous atmospheric pollutant is SO_2. The material was taken from the trees and bushes growing in "control" plants 65 km from Severonikel and in "experimental" plants 10 km from the smelter. The intact chlorenchyma cells of the needles and leaves of the control and experimental plants were investigated. The dynamics of mitochondria and chloroplasts in the chlorenchyma cells of the pine needles and bush leaves were determined. The chloroplast number in the mesophyll cells of the investigated species was not dependent on the impact of atmospheric pollutants. The mitochondria number increased in the experimental plants, especially in the three-year-old pine needles (on 107%) and at the current-year pine needles (on 88%) and at one- and two-year-old red bilberry leaves (on 94%). It was concluded that the increase of mitochondria is the response of plant cells to stressful conditions.

THE STRUCTURE OF CHLORENCHYMA CELL LEAVES OF PLANTS GROWING AT WRANGEL ISLAND AND NOVAJA ZEMLYA ARCHIPELAGO

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Wrangel Island and the Novaja Zemlya archipelago are situated at latitudes higher than 70°N. Nuclear explosions were carried out in open space in the Novaja Zemlya archipelago from 1955 to 1962. Thus, it might be meaningful to compare the leaf cell structure of the plants growing on Wrangel Island and on the Novaja Zemlya archipelago. Foliar specimens were collected and preserved from Wrangel Island in the middle of July 1982 and from the Novaja Zemlya archipelago during July 1992. Leaf samples were obtained from plants during their flowering period. They were initially prepared for electron microscopy. A comparative analysis was made of the data regarding ultrastructural differences in leaf chlorenchyma cells from the same species (*Astragalus alpinus, Poa alpina, Ranunculus sulphureus*) growing at both island and archipelago. Essential differences in the structure of chlorenchyma cell leaves among the species compared were not revealed. Preliminary data about the cytoplasma structure of the investigated species have been obtained. These investigations will be carried on and the number of species compared will be increased.

The accumulation of Aufeis *along the banks of swift moving streams and rivers can be several meters thick in mid-summer, Alaska, U.S.A.*

CRITICAL LOADS OF ACIDITY TO SURFACE WATERS IN THE SVALBARD AREA

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The internationally accepted definition of critical loads is: "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements do not occur according to present knowledge." A method for calculating critical loads and exceedances of critical loads of acidity to surface waters is based on the acid neutralizing capacity (ANC) of the water. ANC is defined as the difference between the sum of base cations (Ca + Mg + Na + K) and the sum of strong acid anions ($Cl + SO_4, + NO_3$). Critical loads (CL) and exceedance of critical loads (CL_{ex}) for input of strong acids to surface waters at Svalbard are calculated according to the following equations (modified after Henriksen et al., 1992):

$$CL = ([BC]^*_t \div ([SO_4]^*_t \div [SO_4]^*_d) \div [ANC_{limit}])Q \div BC^*_d$$

$$CL_{ex} = SO_4{}^*_d + NO_{3\,le} \div BC^*_d \div CL$$

where:

$[BC]^*_t$ is the concentration of nonmarine base cations in a surface water sample (μeq/L).

$[SO_4]^*_t$ is the concentration of nonmarine sulfate in a surface water sample (μeq/L).

$[SO_4]^*_d$ is the concentration of nonmarine deposition of sulfate in the catchment (μeq/L).

$SO_4{}^*_d$ is the annual nonmarine deposition of sulfate in the catchment (keq/km^2/yr).

ANC_{limit} is the critical biological value (limit) for ANC of the water; 20 μeq/L is an acceptable ANC_{limit} for fish and invertebrates.

Q is the runoff from the catchment (L/sec/km^2).

BC^*_d is the annual nonmarine deposition of base cations (keq/km^2/yr).

$NO_{3\,le}$ is the annual leaking of nitrate from the catchment into the surface water (keq/km^2/yr); = nitrate concentrations measured in the surface water sample × Q.

The calculations were based on 162 water samples from Svalbard and Bjørnøya. The samples were analyzed for pH, alkalinity, conductivity, turbidity, Ca, Mg, Na, K, SO_4, Cl, Tot-N, NH_4, NO_3, Tot-P, TOC, and fractions of aluminum. A map showing annual precipitation on Svalbard has been prepared. Colored maps for critical loads and exceedance of critical loads have been prepared for Svalbard and Bjørnøya. Twelve percent of the ice free area of Svalbard (about 3400 km^2) has low critical loads, less than 25 keq/km^2/yr or 0.4 g S/m^2/yr. These areas were found mainly in the northern part, but also were scattered around all over the islands. Two-thirds of Svalbard is well protected against acidic precipitation with a critical load of more than 100 keq/km^2/yr or 1.6 g S/m^2/yr. Five percent of the ice free area of Svalbard (about 1500 km^2) shows exceedance of critical loads. The exceedances are small, less than 25 keq/km^2/yr using an ANC_{limit} of 20 μeq/L. These areas are all located in the northern part of the islands.

BIOLOGICAL IMPLICATIONS OF CHEMICAL CONTAMINANTS IN THE ARCTIC

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The last two decades have furnished a growing body of literature describing the import of numerous trace contaminants into the Arctic. These contaminants typically originate with chemical-consuming activities at temperate latitudes, notably the combustion of fossil fuels and the application of stable pesticides. Arctic sampling programs have described the presence of these contaminants in numerous media—air, water, aquatic sediments, snow, plants, animals, and soils. The interest has focused largely on understanding the sources and pathways by which these materials reach the Arctic, with the result that we know a great deal about what is there but very little about what that might mean biologically. Indigenous arctic people typically consume relatively large proportions of meat in traditional diets, and so the most highly valued ecosystem components are animals that supply meat for human consumption. These include large mammals such as seals, whales, walrus, and caribou, and several species of birds and fish. The largest among these are not suitable for toxicological study for obvious reasons of cost, although a few such experiments have been done (mink, seals, dolphins, polar bears). There are several approaches with potential to comment on the biological implications of the contaminant measurements. The first of these is simply the measurement of the chemical residue itself. If a measurement of residues in an organ believed to be a toxicological target can be compared with similar measurements from other species undergoing experimental treatments, then some tentative relationship between residue and toxicological endpoint may be inferred. A second emerging technology is that of "bioindicators," in which animals are examined for responses associated with known exposures from laboratory experience and from field experience with other sites and species. A third approach is the field experiment, in which animals (or even whole small ecosystems) are treated and then monitored to determine what outcomes will follow. These approaches are in various stages of application in the Arctic, and they are suggesting very subtle effects, even at the low residue levels reported.

AIR POLLUTION, FOREST DECLINE, AND NUTRITIONAL DISTURBANCES IN NORTHERN CHINA

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In 1989, the Chinese Academy of Forestry initiated a multidiscipline preliminary study on the decline and death of *Larix gmelini Rupr.* in northern China (54°N), and in February 1990, the first study report on air pollution and forest decline in northern China was published. Since then, the study and discussion on the cause of forest decline in northern China have included the effects of air pollution on the forest, rather than merely examining the cause of disease and insect pests in the past.

Preliminary investigation in the area shows that needle chlorosis (yellowing) of *Larix gmelini Rupr.* is a common symptom of forest decline in the mountainous region, and a significant increase of this symptom has been seen for the past years. SO_2 and rain pH data were collected from three monitoring sites in the area. Soil and needle analyses were carried out. Preliminary results indicate that yellowing was evident at all sites with lower soil pH, and, concerning soil nutrient status, Mg deficiencies were most notable in acid soils with percent base saturation of 3.2–7.5%. Mg, K, and Zn (particular Mg) concentrations in current needles were all deficient. Exchangeable Mg in the soils of heavily damaged forest stands was lower than that in the soils of well-growing forest stands. The degree of yellowing, however, does not rise along with an increase in Al concentration. Preliminary investigation in the north indicates that forest damage is associated with nutritional disturbances, and that magnesium deficiency is the most predominant agent in causing symptoms of yellowing foliage.

PRODUCTS OF NUCLEAR FISSION AND NATURAL RADIOACTIVITY IN CARIBOU IN CANADA

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The major part of radioactive contamination carried into the Canadian Arctic has been fallout from the testing of nuclear weapons in the atmosphere, a practice that effectively ceased in 1962. The movement of fallout through ecosystems can be described as following from a pulse in the early 1960s. Now, only long-lived fission products such as ^{137}Cs are of concern.

Debris from large nuclear explosions is carried into the stratosphere and returns to earth as fallout over several years. In temperate zones, human and domestic herbivores depend on annual crops and deciduous plants. The ^{137}Cs ingested is fallout intercepted by plants during one growing season; ^{137}Cs that reaches the soil as fallout or is shed over the winter is sequestered by the mineral fraction of the soil and is not available to the next year's plant growth. In the Arctic, plants recycle cesium more readily and lichens retain the fallout they intercept. Thus contamination by fallout of plants and the meat of herbivores, particularly caribou, persisted for many years. By 1986, the concentration of ^{137}Cs in caribou meat had fallen to about one-tenth its value in the 1960s.

Debris from the fire at Chernobyl was transported in the troposphere and was deposited unevenly around the globe, much more heavily closer to the source. In Canada, ^{137}Cs from Chernobyl added only 25% to the residual fallout found in caribou meat. Radon emanating naturally from the ground is an ongoing source of airborne radioactivity deposited on lichens and transferred to caribou. ^{210}Pb, the long-lived product of the decay of radon, persists as a radioactive contaminant.

The radiation dose to consumers of caribou in Canada from ^{137}Cs is today about the same as that from ^{210}Pb and its immediate decay product, ^{210}Po, and the two sources together roughly equal the exposure from normal background radiation.

EVOLUTION OF THE ARCTIC SYSTEMS

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Evolution of organisms and evolution of the biosphere are two interrelated processes. The structure and functions of the biosphere do not remain invariable, but are changing, together with the changing morphophysiological properties of organisms. The evolution of living matter is directed toward maximum manifestation of the aggregate organizing force of the organisms, which is revealed in their nourishment, respiration, and reproduction; organization of the biosphere is an expression of the biogeochemical functions of living matter. Three basic processes—photosynthesis, feeding relations, and decomposition—are the most important features of the ecological process.

In the Arctic, ecological systems are being simplified and are becoming "younger." Spatially, climax and pioneer successional stages exist close together. Most of the energy and oxygen is spent on the restoration of disrupted ecosystems.

A criterion for this evolution is the interrelationships among creation, accumulation, and decomposition, which are controlling the continuous cycle of matter and energy. Several decades of industrial development have been enough to disrupt this dynamic equilibrium. The biosphere's evolutional response to possible disruptions in its development is organized diversity.

The following basic functions of living matter in relation to the Arctic are discussed: gas function, concentration function, reduction-oxidation function, biochemical function, and human biogeochemical function, as well as the structural evolution of Arctic communities.

DEGRADATION OF SOIL AND VEGETATION UNDER AIR POLLUTION IN NORTH EUROPEAN RUSSIA

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Nowadays, technogenic sulfur and heavy metals penetrate into the arctic atmosphere in great amounts due to the combustion of fossil fuel and the metallurgical industry. This leads to a substantial rise in the amount of contaminants in ecosystems. Soils represent a final biogeochemical barrier against basic contaminants. However, long-term air outbursts from copper-nickel industry wastes in the Kola Peninsula result in soil pollution, especially the upper horizons. Approaching the emission source (Severonikel smelter complex), the gross content of Ni, Cu, Co, and Fe in soil and the concentration of motile forms available for plants increase. The status of vegetation is worsening gradually. An increase of over 200 mg/kg in the total amount of motile forms of Ni and Cu in the humus-accumulative horizon causes damage to the root system and leads to growth suppression and visible worsening of above-ground organs. Further increase in pollutant concentration leads to total dying off of plants from forest canopies and damage to and decay of terrestrial plant organs. Close to the source of emission, a technogenic desert forms, with vegetation completely destroyed and soil washed away and destroyed down to horizon B.

AIRBORNE CONTAMINANTS BY HEAVY METALS IN THE FRESHWATER ECOSYSTEMS OF THE KOLA SUBARCTIC REGION (RUSSIA)

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The copper-nickel smelter complexes of Kola Peninsula are powerful sources of atmospheric contamination by heavy metals (Ni, Cu, Co, Cd, etc.) and acidic oxides, which, deposited in precipitation, cause negative effects on local freshwater ecosystems. The rise of background levels of heavy metals occurs over large areas in the region. The highest concentrations of metals in a 30-km zone near sources causing toxic effects on fish were recorded. Changes in population and organism indices followed the accumulation of heavy metals in water ecosystems. A shift in mean population age and in mature to juvenile stages was found. In fish, pathologies occur in vital organs: gills, liver, kidney, etc. The concentrations of trace elements in fish significantly exceeded those in water. A relationship was found between concentrations of heavy metals in water and extent of fish pathology. The critical loads of heavy metals total effects for arctic freshwater ecosystems was determined.

THE RESPONSE OF LICHENS TO ATMOSPHERIC DEPOSITION WITH AN EMPHASIS ON THE ARCTIC

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Lichen-dominated ecosystems occur extensively in arctic regions, where they support extensive caribou and reindeer herds. Because they lack root systems or other absorptive organs, they are dependent primarily on atmospheric sources of nutrients. As a consequence, they are efficient accumulators of atmospheric deposition, whether nutrients or contaminants are present. This was well demonstrated in the accumulation of radionuclides along the lichen-caribou-human foodchain during the 1960s. As lichens are a principal component of arctic terrestrial ecosystems, the effects of contaminants on lichens are of major concern, particularly as lichens are among the most sensitive bioindicators of air pollution. This paper reviews the uptake, localization, and effects of acidic aerosols, organics, radionuclides, and trace elements on lichens. Emphasis is placed on studies conducted in the Arctic or on laboratory investigations with arctic species.

ECOSYSTEM MAPPING OF THE AREAS DAMAGED BY INDUSTRIAL AIR POLLUTION ON THE KOLA PENINSULA (RUSSIA)

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The area of ecosystems damaged by air pollution occupies about 53,000 km^2 on the Kola Peninsula. Mapping was based on a classification of ecosystems, taking into account their dynamics. Data collected at 500 sample plots, as well as the results obtained by V. Alexeev, V. Gorshkov, V. Kruchkov, V. Nikonov, V. Yarmishko, and others, has been used in the ecosystem classification. The cover percentage of moss layer species, age of needles, portion of damaged trees, cover of epiphytic lichens and their floristic composition, and some other characteristics were used to identify stages of ecosystem degradation under the influence of air pollution. The Lapland State Reserve (LSR) was a key area for which the vegetation map at a scale of 1:50,000 was produced (Yurkovskaya and Holod, eds., 1992). The ecosystem map of the LSR and surrounding territories disturbed by intensive air pollution was compiled by means of computer interpretation of space images.

RADIONUCLIDES IN THE MOSS-LICHEN COVER OF TUNDRA COMMUNITIES IN THE YAMAL PENINSULA

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Intensive economic development of the Yamal Peninsula, its proximity to nuclear polygons in Novaja Zemlya, and poor knowledge of radioecological situations have made it essential to estimate the degree of radioactive pollution of the soil-vegetative cover in the area. Lichens and mosses were used as biological indicators. It has been established for the first time that ^{90}Sr concentrations in lichens and mosses belonging to different taxa varied from 30 to 160 Bq/kg in dry mass and that concentrations of ^{137}Cs varied from 50 to 410 Bq/kg, correspondingly. In general, concentrations of radionuclides in these plants change within the limits of values of the same order of magnitude; the observed differences are connected with biological properties of species, age of plants, and dissimilarity of sampling plots. It is shown that concentrations of radionuclides in mosses and lichens of the far north have declined 3–7 times on the average when compared with maximum values recorded in 1964–65. During the same period, soil pollution density (5 cm layer) has diminished from 0.034 Cu/km^2 to 0.017 Cu/km^2 for ^{90}Sr and from 0.048 Cu/km^2 to 0.031 Cu/km^2 for ^{137}Cs. Data for the contents of radionuclides in moss-lichen communities and components of the soil-vegetative cover are presented. For all radioecological parameters studied, no pollution with ^{90}Sr or ^{137}Cs was detected in the area.

TRICHLOROACETIC ACID AS AN AIRBORNE HERBICIDE AND AN INDICATOR FOR OTHER PHYTOTOXIC PHOTO-OXIDANTS

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Various ubiquitous volatile organic air pollutants, especially C_2 halocarbons, may be converted to secondary air pollutants that are phytotoxic and known as herbicides. One of these is trichloroacetic acid (TCA), found in concentrations in the range of 10–130 ng/g in the foliage of northern forest trees in Finland. TCA has been used as a herbicide against monocotyledonous. It has formative effects, inhibits growth, and induces chlorosis and necrosis of light-exposed leaves, including woody plant species. Twenty Scots pine trees were sampled for correlation of TCA levels and needle loss in northern Finland. The trees located at the northwesterly edge of the stand could be clearly divided into two groups, according to their susceptibility to TCA. The extent of defoliation was low in one group, with a gradient of 0.32% defoliation per unit TCA concentration; in the sensitive group, the correlation line had a steeper slope of 0.78% defoliation per unit TCA concentration. These two groups serve as a good basis for further studies on morphological, anatomical, and biochemical characteristics. The more potent monochloroacetic acid (MCA) has been found in concentrations similar to those of TCA. Fluctuations in MCA levels seem to follow those of TCA. The latter, for which most data have been collected up to now, may turn out to be of less relevance, but yet may serve as an indicator for the distribution and deposition of other phytotoxic photo-oxidants.

ECOLOGICAL EFFECTS OF AIRBORNE CONTAMINANTS IN ARCTIC AQUATIC ECOSYSTEMS: A DISCUSSION OF METHODOLOGICAL APPROACHES

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Studies of pollution problems in rural areas of the world have stressed the importance of "clean, unpolluted" reference areas in the polar regions to be used for comparison to the more polluted and contaminated areas. However, long-range transport of contaminants and pollutants to these "clean and unpolluted" polar ecosystems has been recognized during the last decades. The reason for our concern is the risk of detrimental effects of environmental contaminants on biota in various parts of the biosphere, including the polar regions. The choice of methods to be used to study the biological effects of contaminants on arctic ecosystems can be divided into measurements of contaminant parameters (concentrations), physiological parameters, morphological parameters (histology, etc.), and population and community parameters. All the various kinds of measurements given above have disadvantages and advantages. The choice of methods to be used is a result of the conception behind the studies and our ability to formulate specific risk models to be investigated. The selection of investigative methods is discussed on the basis of our aim to cover expected or unexpected effects of known and unknown contaminants in the arctic region, where, from a worldwide perspective, the concentrations at comparable ecological niches are low.

MORPHOLOGICAL CHANGES OF TERRICOLOUS LICHENS (CLADONIACEAE FAMILY) AS AN INDICATOR OF ECOLOGICAL CONDITION IN SIBERIAN SUBARCTIC ECOSYSTEMS

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Morphological changes in terricolous lichens have often been reported in the literature for Cladina species exposed to simulated acid rain. These lichens are widely distributed in the northern subarctic areas of the Krasnoyarsk District, which for more than 50 years has been subjected to acidic deposition from the Norilsk industrial complex. Sulfur emissions in this area are estimated to be as great as 2.3 million tons per year. During 1990–1992, lichen species were collected from 30 sites (from heavily impacted to presumably unaffected by pollution) in different directions from the source of pollution (50–300 km south-southeast, 10–120 km west-northwest, 10–150 km east-northeast).

To date, about 40 species (genus Cladina and Cladonia) have been identified and about 20 of these exhibit morphological changes, deformities, and damage such as the following: change of podetia and apothecia color; disturbance of apical branching types; appearance of growth abnormalities such as "stunted branching," "thors," and "adventitious branching"; appearance of large numbers of asexual structures; deformity and growth decrease in podetia; deformity and disturbance of podetia external surfaces; damage to podetia by "acidic burn." It has also been indicated that all apical and adventitious tips of Cladina and some Cladonia species are white or yellowish in appearance, which is a result of the absence of algal cells in podetia tips. This symptom may be the earliest sign of toxic sulfur inputs. Thus, our field observations of the northern ecosystems of the middle Siberian plateau (Krasnoyarsk region) on the condition of lichens show varying degrees of their decline.

THE COMPLEX SIMULATION OF THE EFFECTS OF ROCKET FUEL SPILLS ON THE NATURAL ENVIRONMENT OF AREAS OF THE EXTREME NORTH OF RUSSIA (163-D)

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Using methods of mathematical simulation on a regional scale, we investigated the environmental impact of the deposition of liquid rocket fuel residues resulting from the drop of first stages of rocket-carriers launched from the northern cosmodrome, Plisetsk. A simulation approach proposed by J. Onishi showing the transport of chemical substances in the environment is described. An evaluation is given of the transformation of chemical substances and their migration along the food chains as described by J. Bolten, with coauthors P. Richi and M. Ruvie. As a base for simulation, we used experimental data on the decomposition of rocket fuel and on the migration and accumulation of decomposed products collected in vegetation of areas in the extreme north. A model of winter and spring pastures for northern deer has been created on the basis of known algorithms for the "herd-forage base economy." The effects on population are simulated taking into account the three main processes of xenobiotics reception: alimentary, contact, and inhalation. We built probability estimates of the development of toxic damages at individual and population levels, by applying known mathematical relationships of the "time-dose-effect" type. We verified the model and its separate components using extensive field survey data.

IMPACTS OF AIRBORNE CONTAMINATION ON EAST EUROPEAN ARCTIC ECOSYSTEMS

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Technogenic impacts on high arctic ecosystems are intensified by the rigorous climate. Anthropogenic transformation of terrestrial ecosystems in the area of Vorkuta is caused by cement and coal dust. Changes in soil chemical parameters (alkalinization, replacement of H, Al by Ca, Mg in the base-exchange complex), and local disturbance of the genetic matrix have been observed in tundra surface gley soils (gleysolic turbic cryosols). In thin sections, the fabric was dominated by calcite and coal skeleton grains and showed evidence of plant residue decomposition. Observations of the microfabric in surface and subsurface layers suggest that air contamination has led to the weakening of eluvial and strengthening of biogenetic-accumulative processes. The influence of dust on soil cover has caused a rise in surface temperature and an increase in thermokarst danger. Plant communities undergo losses of acidophile lichens, and there is a prevalence of calciphile mosses and depression of growth in dwarf bushes. In soil algae communities, we see origins of new species, changes of dominants, and quantitative alignment. Increase of N-fixing activity of *Nostoc commune Vauch.* (154%) and *Peltigera ruf* (38%) has been observed. Instead of the thin algae films seen in control sites, compact round shaped colonies in moss cushions are formed in contaminated sites.

ON THE PROJECT "ECOLOGICAL ATLAS OF THE RUSSIAN ARCTIC"

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The aim of the Ecological Atlas of the Arctic is to show the real condition of arctic and subarctic ecosystems using cartographic methods to identify the most endangered territories and to suggest ways of sustainable use of natural resources. The volume is supposed to include more than 150 pages, measuring 36 × 60 cm. Three sections are planned for the Atlas. Section A, the introduction, will give a brief outline of the natural arctic environment, emphasizing its severe conditions for human life. Section B, on ecological potential and the present condition of natural systems, will include general maps depicting sources of anthropogenic influence. It is intended to consider different components of terrestrial natural systems, the changes these systems undergo because of anthropogenic impact, and sometimes a prognosis of future change; physical and chemical characteristics of the biota and of water masses of rivers and seas will be given, as well as present levels of pollution, and the possible changes to be expected under landscape climatic changes and technological impact. Section C, on humanity and the sustainable use of nature, will present maps of population density and national composition; natural resources of land, sea, and terrestrial waters will be considered. Cartographic information will be given on the condition of population health. The problems of conservation, preservation of the gene pool, and biodiversity of the region will be considered as well.

EFFECTS OF AIRBORNE CONTAMINANTS ON NORTHERN AQUATIC ECOSYSTEMS

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Trace concentrations of organic pollutants and trace metals are known to occur in precipitation in the most remote parts of the northern hemisphere. While concentrations of these contaminants in rain and snow are usually scarcely detectable, in many cases, they have contaminated aquatic fauna to concentrations where effects on upper members of aquatic food webs, including risks to native human populations, are of concern. Studies of sediment cores from freshwater lakes indicate that this contamination has happened largely in the last 60–80 years.

The high degrees of contamination found in arctic ecosystems are caused by several factors, including transport from more populous southern regions by seasonal wind patterns, atmospheric distillation, simple food chains, the lipophilicity of many contaminants, and the tendency for northern organisms to contain high concentrations of fat as energy reserves to survive long winters. Biomagnification in northern aquatic food chains often causes carnivorous organisms to contain contaminants at concentrations that are one million to one hundred million times higher than in precipitation.

Few studies on effects are available. Invertebrates and lower trophic levels appear to be unaffected by airborne deposition, but sublethal effects have been documented in carnivorous fish. Fish-eating birds and mammals appear to be at higher risk, due largely to high rates of biomagnification. Reproductive impairment and behavioral changes have been documented in some studies.

Concentrations in native foods in some areas of Canada have become high enough to require consumption advisories for humans. Higher than normal rates of consumption, mistrust of regulatory agencies, and the lack of alternative food sources make native populations a topic of special concern.

The persistence of many airborne toxins in aquatic environments requires that they be regulated more cautiously than is customary for substances of higher degradability. Half-times for disappearance of many toxins in ecosystems where regulations have been imposed often span one to several decades.

THE ASSESSMENT OF LIGHT FOREST DEGRADATION BY TREE-RING ANALYSIS IN THE NORILSK INDUSTRIAL AREA

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A partial or total dying off of spruce-larch forests has been observed in the area of 0.55 million ha (data for 1988) in the zone around the Norilsk mining and metallurgical group of enterprises with sulfur dioxide emissions of more than 2 million tons per year. For the spatial-temporal evaluation of forest degradation, a death time of trees was estimated and an analysis of radial tree growth under the influence of natural and technogenic factors was made. It is shown that before the beginning of contamination, the variability of tree-width indices was determined mainly by the thermal conditions in June and July of the current year; in cool years and periods, the influence of July temperatures increases as compared with temperatures in June. The reduction in tree growth due to air pollution began in the mid-1960s, that is, nearly 15 years before the mass dying off of trees. At present, the difference between the actual and expected ring-width indices reaches 60–100%. The influence of pollutants on tree growth reduction has been observed at a distance of 170 km from the source of emission. As they grow, larch trees are more sensitive to pollution than spruce. To reduce the effect of pollution on forests, it is necessary first to diminish the emissions into the atmosphere that occur in July.

HEAVY METALS IN THE SOILS OF SØRKAPP LAND, SOUTHWEST SPITSBERGEN, AND SVALBARD

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Research on the occurrence of heavy metals (Pb, Zn, Cd) in the southern part of Spitsbergen is presented. This region is situated in the northwestern part of Sørkapp Land, which is a part of the Norwegian National Park on West Spitsbergen (Svalbard Archipelago). The soil cover of this region was formed on contemporarily nonglacialized seaside plains (Kulmstranda, Hornsundneset, Breinesflya, Tørrflya) and mountain slopes (Hohenlohefjellet, Iddfjellet, Wiederfjellet). Soils formed there are the arctic tundra variations of the cryogenic soils (Pergelic: Cryorthents, Cryaquepts, Cryochrepts, Cryofibrists). The quantity of the indicated heavy metals is as follows: Pb, ~4.30–39.83 ppm; Zn, 2.9–98.66 ppm; Cd, 0.14–0.66 ppm. The increased concentrations of those metals, especially zinc, is a concern in the soils of the Breinesflya seaside plains and the slopes of Wiederfjellet. Most likely, this results from the occurrence of those elements in bedrock (parent material) of these soils (fyllite of Heclas Hoeck formation, triassic dolomite). The concentration of heavy metals in other parts of the described region can be described as not being affected by the emission of industrial dust from air pollution.

ANALYSIS OF THE SCOTS PINE RENEWAL PROCESS IN POLLUTED AND UNPOLLUTED AREAS OF THE KOLA PENINSULA

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The renewal process of Scots pine was studied in primary (age 200–300 years) and secondary (age 35–45 years) lichen pine forests located at a distance of 8–75 km from the Severonikel smelter complex. It was found that within the zone of damaged ecosystems (30 km from the smelter), the development of new pine generation under the canopy of pine forests was going on and the age structure of seedlings was similar to that in the control areas. Significant negative impacts of air pollution on the density of seedlings were observed only in old pine stands. Under conditions of high levels of air pollution (the zone of destroyed ecosystems, 12 km from the smelter), a substantial decrease in seedling density, compared with control communities, was observed both in primary and secondary Scots pine forests. Profound changes in the age structure of seedlings (absence of many age groups) related to the ending of development of new pine generation was characteristic of destroyed old pine stands.

MONITORING AIR POLLUTION EFFECTS ON TERRESTRIAL ECOSYSTEMS IN VARANGER (NORWAY) AND NIKEL-PECHENGA (RUSSIA) USING REMOTE SENSING

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NORUT conducted a research project concerning the effects of air pollution on terrestrial ecosystems in the Varanger area (Norway) and Nikel-Pechenga (Russia) during 1988–1993. Air pollution emanating from the nickel-processing industries in Nikel-Pechenga and Monchegorsk on the Kola Peninsula (Russia) are the main contributors to the environmental problems on the Norwegian side of the border between Norway and Russia. The study area covers approximately 10,000 km^2 and comprises parts of Russia, Norway, and Finland. In order to maintain environmental surveillance over the extensive border area, NORUT used satellite remote sensing data in combination with ground truth measurements. The main objective in this project was to assess the feasibility of using optical remote sensing (Landsat MSS data and Landsat TM data) to map vegetation cover changes in the period 1973–1988 related to the impacts of air pollution in the border areas between Norway and Russia. During the project, we produced vegetation maps for four different years (1973, 1979, 1985, and 1988), change detection maps, and statistics. One of the main changes in the vegetation maps produced for the different years was that the area dominated by dwarf shrub-lichen vegetation cover types had decreased from 2569 km^2 in 1973 to 405 km^2 in 1988. Bare rock, eroded heath, and contaminated (damaged) areas had increased from 257 km^2 in 1973 to 1324 km^2 in 1988. Comparison of the vegetation cover maps and the change detection maps with the total number of emissions of SO_2 presented shows a strong correlation between the dwarf shrub-lichen cover changes in the forests and heath land and the dramatic increase of emissions in the period 1973–1988. The area damaged and affected by air pollution increased from approximately 400 km^2 in 1973 to more than 5000 km^2 in 1988. This study shows that the critical loads of air pollution are being exceeded for the dwarf shrub-lichen heath, and for the birch and pine forests dominated by dwarf shrub-lichen in the eastern parts of the study area. The biodiversity has also decreased in the eastern part of the study area near the melting factories in Nikel-Pechenga. In the end, this study concluded that the use of optical remote sensing (Landsat MSS data) for mapping of vegetation cover changes related to the impacts of air pollution was successful.

VEGETATION COMPONENTS OF ARCTIC ECOSYSTEMS

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Arctic vegetation has developed under extreme environmental conditions and therefore has a different composition and structure compared with vegetation of the temperate zone. This difference is indicated in (1) the shift in floristic composition towards cryptogamic plants and bryophytes along the gradient from southern tundras to polar deserts (coefficient of lichens and vascular plants is 2:1 in the first case and up to 20:1 in the latter case), (2) the suppression of vertical structural elements into one or two layers, (3) the change in importance of different coenoelements along the south to north gradient, and (4) the increase in the openness of the vegetation cover towards the north. For arctic vegetation, it is expedient to determine three levels of organization: (1) coenoelements (intracommunity units such as coenocells, guilds, and synusiae), (2) communities, and (3) coenocomplexes. Synusiae in arctic vegetation have a specific feature: different life forms are packed into dense but thin layers (compressosynusiae). They exist in complexes with simple synusiae consisting of only one life form. The structure of arctic vegetation becomes considerably simpler from south to north. The polar deserts are characterized by fragmocoenoses that actually are complexes of compressosynusiae, simple sunusiae, and guilds. A characteristic feature of tundra vegetation is the dominance of microcoenoses (coenoses of small area and pauperized composition) and multistratal eucoenoses. A characteristic of arctic vegetation is its diverse complexity--nano- and macrocomplexity in polar deserts, mesocomplexity in northern tundras, and macrocomplexity in southern tundras. Different structural components of arctic vegetation have different tolerances to anthropogenic impact, especially to airborne pollutants. The scarce and simple vegetation of northern areas is much more sensitive to disturbances than is vegetation of more southern tundras.

AIRBORNE HEAVY METAL POLLUTION FROM THE PECHENGA NICKEL COMBINATE AND THE DIFFERENT IMPACTS ON *VACCINIUM MYRTILLUS L.* AND *EMPETRUM NIGRUM L.* SUBSP. *HERMAPHRODITUM* (HAGERUP) BÖCKER IN SØR-VARANGER, NOP.THERN NORWAY

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Plant and soil samples were taken from Sør-Varanger, northern Norway, in order to determine the amount of airborne pollution in this area related to the activities of two Russian nickel smelters, situated close to the Norwegian border. The sample plants taken were *Vaccinium myrtillus*, a deciduous dwarf shrub, and *Empetrum hermaphroditum*, an evergreen dwarf shrub. These were chosen to investigate the effects of airborne heavy metal pollution on different plant species. Leaf samples were analyzed for nickel, micronutrients, and all macronutrients, except nitrogen. Plant available Ni and Cu were extracted from organic and illuvial horizons of podsol profiles. The results show that the accumulations of Ni and Cu in the organic top soil depend on distance and exposure to the pollution source. Higher extractable Ni concentration in the upper layer corresponded with higher values from the illuvial horizon, indicating migration of Ni through the profile. A positive correlation was found between Ni in soil and Ni in plant tissue for both horizons. Green leaves of *E. hermaphroditum* had distinctly higher concentrations of Ni than those of *V. myrtillus*. Particularly high levels of Ni, Cu, Fe, and Al were measured in the older leaves of *E. hermaphroditum* in the most polluted areas, indicating accumulation of these elements over time. In some cases, this may have reached a level harmful to plants. Differences in life strategies between evergreen and deciduous dwarf shrubs in the arctic environment seem to be responsible for higher metal concentration in *E. hermaphroditum*.

AL:PE 2 - ACIDIFICATION OF MOUNTAIN LAKES: PALEOLIMNOLOGY AND ECOLOGY, REMOTE MOUNTAIN LAKES AS INDICATORS OF AIR POLLUTION AND CLIMATE CHANGE

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Remote mountain lakes are defined as high-altitude or high-latitude sites situated above or beyond the local tree line, respectively. They are remote from catchment-based disturbances associated with land use changes or waste water pollution and are consequently most sensitive to changes in air quality and climate. In areas of Europe with high sulfur and nitrogen deposition (e.g., Scotland, southern Norway, some Alpine sites, Tatras), many remote lakes are polluted by acidity, trace metals, carbonaceous particles, and persistent organic pollutants (PCBs, etc.) as a result of long-range transported air pollution. In cleaner areas, for instance in the Pyrenees, central Norway, and Svalbard, lakes are less affected, and some may be unpolluted or "pristine." It was the function of the STEP project AL:PE 1 to assess the acidification status of some of these lakes, and in the succeeding AL:PE 2 project, we extend the study to cover new sites in additional countries and mountain ranges and implement a more extensive chemical and biological investigation program. The similarities and dissimilarities in water chemistry and biology in the high mountain areas in several European countries and the arctic areas at Svalbard will be studied. Also, the development of Europe-wide ecological models for mountain lakes is the responsibility of the project. The AL:PE 2 project was launched in January 1993, and summer 1993 will be the first sampling period. AL:PE 2 is a cooperative project among 15 institutions in 8 European countries, covering an extensive program of water chemistry, sediments and diatoms, zooplankton, invertebrates, and fish. The results will be used for statistical analysis and modelling. Each of these six subject areas has a coordinating country and person. AL:PE 2 will continue for two years. The poster presentation will give an overview of the project plans and working methods. AL:PE 2 is supported by the Commission of European Communities Environment Programme, the Norwegian part by the Royal Norwegian Council for Scientific and Industrial Research.

ECOLOGICAL EFFECTS OF AIRBORNE CONTAMINANTS ON FRESHWATER PHYTOPLANKTON, ZOOPLANKTON, AND ZOOBENTHOS IN THE KOLA PENINSULA

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This study presents some results of the biological research carried out on more than 100 lakes, rivers, and streams of the Kola Peninsula in the Russian Arctic. Phytoplankton, zooplankton, and zoobenthos assemblages are severely affected by heavy metals, sulfate, and mineral dust. The Kola Peninsula is a unique region to study the joint impact of acidification and heavy metal pollution on water biota. The largest amounts of pollutants are believed to have a harmful influence on water biota in the vicinity of nonferrous metallurgical plants where direct toxic effects of heavy metals and indirect impacts due to change of water mineralization and heightened turbidity are prevailing. The impacts of acidification and heavy metals caused by airborne contaminants have also been detected in remote areas. The joint impact of acid compounds and heavy metals is leading to dramatic changes in phytoplankton, zooplankton, and zoobenthos assemblages. Polluted waters are characterized by reduced diversity and number of species, particularly among the relict and other sensitive taxa groups. They are being replaced by cosmopolitic species resistant to pollution and acidification or by species widely distributed in more southern latitudes. Heavy metals concentrations in benthos specimens are higher in the areas near the main sources of contamination.

THE EFFECTS OF AIR POLLUTION ON PINE STAND ECOSYSTEMS IN NORTH EUROPEAN RUSSIA

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Long-term investigations with the aim of studying and assessing the impact of air pollutants (SO_2 in combination with Ni, Cu, Co, etc.) on Scots pine stand ecosystems were conducted at the Laboratory of Anthropogenic Dynamics of Plant Communities on more than 50 permanent sample plots located at different distances from the Severonikel smelter complex on the Kola Peninsula. It has been established that substantial changes occur in the chemical composition and life activity of plants in all layers of forest communities. As a result, a number of characteristics of plants and communities have been revealed that help to determine the degree of damage and destruction of pine stands. The most informative characteristics are the duration of needle life, the needle store on trees, the amount of healthy trees in stands, the quantity of female cones and the germination capacity of pine seeds, the specific composition and projective coverage of epiphytic lichens in pine stands, and the accumulation of contaminants in plants and soil. Industrial pollution damages the above-ground parts of plants and the structure and functioning of underground parts. Soil toxicity prevents plant growth and regeneration of destroyed communities. Different sensitivities of various plants to a certain type of pollution leads to gradual destruction of the composition, structure, and productivity of forest phytocoenosis and to the decrease in the state of forest vitality and ecosystem productivity. The speed of these changes is directly proportional to the intensity of pollutant impact.

IMPACTS OF AIR POLLUTION ON SCOTS PINE IN FAR NORTH, RUSSIA

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The impact of chronic air contamination by SO_2, heavy metals (Ni, Cu, Co, etc.), and other wastes from the copper-nickel smelter on the structure of Scots pine on the Kola Peninsula was investigated. Negative impacts of contaminants on life duration and status of pine needles, phytomass formation, and growth and status of the skeleton fraction of the crown were recorded. Coverage, as well as needle dimensions and weight, depends both on the branch position within the crown and the distance to the smelter. It was found that the primary reaction of root systems upon soil accumulation of toxic substances was intensification of mycorrhiza formation in thin roots. Approaching the source of emission, growth depression, worsening of vitality, and gradual dying off of thin roots, and later on all other root thickness categories, were observed. The destructive impact of air pollution on the formation and development of forest ecosystems is most obviously seen in the crown of Scots pine.

REGULARITIES OF IMPACT ZONES FORMING AT THE RUSSIAN NORTH UNDER THE INFLUENCE OF ATMOSPHERIC CONTAMINANTS

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For more than half a century, economic development of Russian arctic and subarctic zones was connected mainly with mining industries (coal, apatite) and nonferrous metallurgy. The use of technologies unadapted to the northern environment, as well as a low degree of ecosystems stability, caused environmental disruption, mainly through atmospheric pollutants and mechanical destruction. Impact zones nowadays occupy 1% of the territory (10,000 km^2). The principal airborne pollutants in the region are SO_2, Cu, Ni, Co, Pb, Sr, etc. The oldest impact zones began to form more than 60 years ago (Severonikel, Monchegorsk, Norilsk, etc.). Younger zones (Nadym, Urengoi, etc.) are connected mostly with oil and gas output. Impact zones have common features: nearly complete degradation of natural vegetation, a high degree of soil destruction, and heavy air, water, soil, and vegetation pollution load (up to 100 times normal). These zones may be determined and regionalized due to certain visible signs and geochemical changes revealed by studies of pollutants in plants (mostly mosses and lichens), soils, snow cover, peat bogs, and lake bottom sediments. Comparative studies of metals concentrations in the environmental media mentioned, both in impact and in background territories, enabled us to determine quantitative criteria for impact zone detection and regionalization, and to find arctic and subarctic background concentrations important for pollution studies.

CONTAMINATION OF THE ENVIRONMENT, AND ECOSYSTEM DEGRADATION IN THE RUSSIAN ARCTIC

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The Russian North occupies 10 million km^2, half the total area of the circumpolar Arctic. The population of the Russian North is about 11 million people, whereas the total population of the circumpolar Arctic is 13 million. Intensive exploitation of natural resources in the Russian North started in the 1950s, and now this region has a fairly well-developed economy and infrastructure. Mining and the consequent refining of metal ores, along with nuclear testing on the Novaya Zemlya Archipelago, results in airborne contamination of the environment and degradation of natural ecosystems. Large industrial centers that exist now in European and Asian sectors of the Arctic will have a tendency to grow, which will result in contamination of the terrestrial and marine environments. A set of maps showing the distribution patterns of sources and consequences of anthropogenic impacts on the environment has been compiled. Evaluation of the current status of ecosystems and tendencies of ecosystems to degrade are given for the Russian Arctic from the Kola Peninsula to Chukotka. It has been concluded that intensification of land use in the Russian Arctic and global climate change can lead to a loss of stability of the global biosphere.

E. CONTAMINANT RELATIONSHIP TO CLIMATE CHANGE

Organizer: Glen Shaw

Purpose: This session is designed to summarize the current state of science, and to assess the research effort needed to better evaluate possible alterations to the climate related to global pollution and contaminants in the Arctic. It will address climatic responses to alterations in cloud microphysics, ice crystal precipitation from clear skies, aerosols and greenhouse gases, and induced climate forcing.

ORAL PRESENTATIONS

8:30 - 9:00	William Kellogg	USA
9:00 - 9:30	Judith Curry	USA
9:30 - 9:50	Jean-Pierre Blanchet	Canada
9:50- 10:10	Knut Stamnes	USA
10:10 - 10:30	Break	
10:30 - 10:50	Leonid Yurganov	Russia
10:50 - 11:10	Sergi Zimov	Russia
11:10 - 11:30	Egizio Corazza	Italy
11:30 - 11:50		

MODEL SIMULATED CLOUD MICRO PHYSICS - RADIATION INTERACTION IN ARCTIC AIR MASS FORMATION

Jean-Pierre Blanchet and Eric Girard, Département de Physique, Université du Québec à Montréal

The rate of air mass transformation from maritime to continental polar air depends on water vapor removal through condensation and precipitation processes. In turn, the removal of atmospheric water vapor reduces the greenhouse effect and enhances the cooling rate of the surface and lower atmosphere. To investigate the role of micro-physical processes during air mass transformation, a detailed column model is developed. This model accounts for gas-to-particles conversion, formation of CCN and ICN, aerosol growth by condensation, coagulation, activation, freezing, and gravitational sedimentation. The aerosol / droplet / crystal spectra are simulated from 0.001 to 500 μm with a multi-level column of the lower troposphere (7 km). The purpose of the model is to investigate the influence on the physical properties of aerosols in the air mass transformation. In particular, the distribution and acidification of aerosol particles may alter water flux, water vapor greenhouse effect, atmospheric temperature, and ultimately, the regional climate.

Arctic haze, scattered light around the sun from the small microscopic particles.

THE EFFECT OF ANTHROPOGENIC SOURCES OF CO_2, CH_2, SO_x, AND NO_x ON CLIMATE AND BIOSPHERE, WITH CONSIDERATION FOR POLAR REGIONS

Evgeniy P. Borisenkov, Main Geophysical Observatory, Karbyshev Str. 7, St. Petersburg 194018, Russia

In most studies on the greenhouse effect, primary emphasis is placed on its effect upon temperature and ocean level rise and the related consequences. This paper contains estimates of the effects of anthropogenic emissions of trace gases (NO_x, SO_x) on the biosphere and on the greenhouse effect, based on mathematical models, with climatic models of zero dimension and box models of basic geochemical cycles. It is shown that, depending on energy development scenarios, the most imminent and most dangerous consequence would be biosphere degradation rather than climatic effects. Based on mathematical models, an explanation is given of variations of CO_2 and CH_4 in the ice core in Greenland and the Antarctic resulting from the effect of climatic changes on the processes of exchange between the atmosphere and the ocean, the atmosphere and the biosphere. This paper discusses the multicomponent structure of the greenhouse effect and its consequences, with consideration for the feedback mechanisms and the features of the contribution of polar regions to this effect.

CARBON MONOXIDE AND HYDROGEN IN ANTARCTICA AND IN GREENLAND

Egizio Corazza[1] and G. Tesi[2]

[1] C.N.R. Istituto Geocronologia, Via Maffi, 36, Pisa 56100, Italy.
[2] Dipartimento Statistica, Università, Firenze, Italy.

Tropospheric mixing ratios of CO and H_2 were determined at the Italian base, Terra Nova Bay, in Antarctica (1989-90 and 1990-91 seasons), and at the European Summit GRIP base, in Greenland (1991 and 1992 seasons), in order to establish the present background in two of the most remote areas in either hemisphere. This kind of research is basic for any inference of global distributions and changes in natural substances and anthropogenic pollutants. Both components were determined by gas chromatography with RGD detector. The concentrations found in Antarctica were: CO = 51 and H_2 = 528 ppbv; CO = 51 and H_2 = 522 ppbv in the two campaigns, respectively. In Greenland, the concentrations were: CO = 114 and H_2 = 548 ppbv in 1991, and CO = 107 ppbv in 1992 (H_2 values were discarded because of pneumatic problems). Peak area calculations and standard calibrations in the laboratory (before and after the campaigns) were performed by means of specially written programs. The instrumentation was automated (one analysis every 2–3 hours) by means of a PC controlling the whole system; series of standards were run every day or every other day. All series of analyses (Antarctica and Greenland) consisted of approximately 200 runs, in order to have a good representation for the brief period (one month). Wind parameters (speed and direction) were also recorded periodically in the Antarctic campaigns and in Greenland in 1991, and continuously in Greenland in 1992. For both areas, some small differences were found between two subsequent seasons, yet the greatest differences for CO in Antarctica were found within the same season, depending on the origin of air masses. For CO in Greenland, differences fell within the range of experimental error, historical and seasonal differences needing longer periods of observation to be detected; relationships with the origins of air masses (polar/North American/European) are still being evaluated.

INTERACTIONS AMONG AEROSOLS, CLOUDS, AND ARCTIC CLIMATE

Judith A. Curry, Program in Atmospheric and Oceanic Sciences, University of Colorado, Campus Box 429, Boulder, Colorado 80309, USA

It has been suggested that the direct and indirect radiative effects of aerosols in the troposphere may be sufficient on a global basis to offset the radiative effects of increasing greenhouse gase~ This talk focuses on understanding these relationships in the Arctic, where potential greenhouse warming has been hypothesized to be the largest of any place on the globe. Direct radiative effects of arctic aerosol include increased atmospheric heating rates and a reduction of surface albedo. Indirect modification of the arctic radiation balance may also arise through the impact of aerosols on the arctic cloud radiative properties. Aerosols modify cloud optical properties by changing the concentration, size, phase, and atmospheric lifetimes of the condensed particles. Increased numbers of cloud condensation nuclei cause a larger number of smaller droplets, resulting in an increase in cloud optical depth and a decrease in precipitation. Additionally, increased sulfate aerosol concentration may depress droplet freezing, increasing the temperature of the transition from ice to liquid phase. Since ice crystals grow much more rapidly than liquid water drops at a given relative humidity and temperature, more water will condense if ice nucleation occurs; however, the ice crystals will fall out of the atmosphere more rapidly due to their larger sizes. In view of the static stability and persistence of the low-level arctic clouds, the impact of aerosols on cloud microphysical and optical properties may be more important in the Arctic than elsewhere on Earth. The possible impact of the direct and indirect radiative effects of arctic aerosol on the radiation balance of the Arctic and sea ice characteristics are investigated using a one-dimensional model of the coupled atmosphere/sea ice system.

GENERAL ATMOSPHERIC CIRCULATION (GAC) AS A MAIN CONTROL OF ARCTIC AIRBORNE CONTAMINANTS AND STATE OF ECOSYSTEMS

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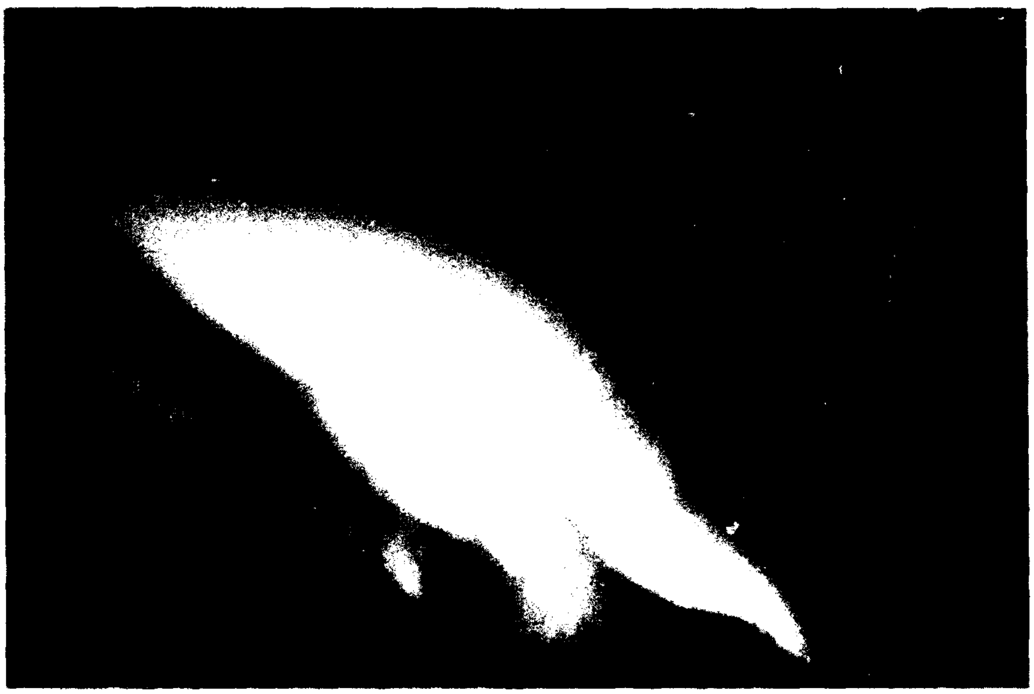
Complex chemical studies based on the Russian high-latitude expedition "North" have shown not only organic pesticides but also heavy metals in snow cover of the arctic seas. It is clear that precipitation and long-range transport of pollutants are responsible for chemical pollution of the arctic atmosphere. Air synoptic analysis of all indicated occasional pollutants provides a background, not only to explain this phenomenon by long-range atmospheric circulation to the Arctic from industrial regions in lower latitudes, but also to recognize the most dangerous sources of contaminants in the northern hemisphere, their general air routes, and the most likely regions of redistribution. The peculiarities of GAC in the far north provide a basis for proposing a preliminary model of pollutant deposition and accumulation. As a result, we can postulate the unique purification role of the Arctic for global biota. It is also presumed that actual global warming during the 20th century appears to be less drastic than expected when the increase of atmospheric CO_2 due to anthropogenical factors was considered as a key factor. The prognostic climatic regime for the coming decade predicts that the current regime will continue.

ROLE OF CHLORINE AND BROMINE CONTAMINANTS IN THE APPEARANCE OF OZONE "MINIHOLES" OVER THE ARCTIC

Igor G. Dyominov, Novosibirsk State University, DAR, Pirogova 2, Novosibirsk 630090, Russia

A numerical, two-dimensional, radiation-photochemistry, microphysical, ozonosphere model has been used to study the winter and spring ozone content in the Arctic at heights of 0 to 50 km. The calculations consider discharges into the atmosphere that contain anthropogenic chlorine and bromine. It has been shown that the ozone "miniholes" observed in February over the Arctic appear only in those regions quite compact by altitude and latitude where polar stratospheric clouds are formed, that is, where temperature does not exceed 190°K. On the particle surfaces in such clouds, heterogeneous processes turn rapidly inert chlorine into active, and active nitrogen to nitric acid. In the presence of anthropogenic chlorine and bromine, this results in a significant increase (by a factor of about 100 at 20 km altitude and 70°N latitude) in concentration of Cl_0, which initiates dimer and chlorine-bromine mechanisms of catalytic ozone destruction. The destruction rate, with stratospheric denitrification by about 75% from February 20 tc March 15, reached 1% a day at the 19–22 km altitude range. The ozone destruction is caused mainly (more than 60%) by Cl_0 dimer. Yet concentration of dimer significantly decreases because of thermal destruction following abrupt warming in late February, and ozone losses sharply weaken.



The aurora curtains over Alaska, a polar phenomenon.

RECENT AND FUTURE CLIMATE CHANGE IN THE EURASIAN ARCTIC

Mariya K. Gavrilova, Permafrost Institute, Siberian Branch, Russian Academy of Sciences, Yakutsk 677018, Russia

Earth's climate is not constant, but changes continually. Throughout the planet's history, warm epochs changed to cold ones and cold periods into warm once again. At present, we are in one of the stages of "cosmic winter," though it is not the coldest. This is reflected in nature, first of all in the biosphere and in "permafrost." Permafrost extended over two-thirds of the territory of western Europe 10–15 thousand years ago; now it occurs mainly in the Pyrenees and Alps, in the Arctic, and in the mountains of Iceland.

Analysis of meteorological materials for the period of observation by instruments, i.e., for the last 100–150 years, shows relative climate stability, which is within the limits of cyclic fluctuations of solar-earth relations. The abnormal "arctic warming" of 1930–40 is an exception. Climate change is also of a regional character. Research in Russia discovered that (1) in the north of European Russia, there is presently a tendency toward climate cooling, (2) western Siberia to the north is neutral, and (3) in eastern Siberia to the north there is a warming tendency.

The prognosis for deviant climate warming in the next century, due to anthropogenic atmospheric pollution, causes much concern. The greatest changes are expected at high latitudes, i.e., in the Arctic. In this study, future air temperatures were mapped for the coldest and the warmest months and for the whole year in the cold regions of Europe and Asia. Scenarios were based on global climate warming of 2°C, by the year 2025, and 3–4°C by 2050, under CO_2 at twice the level of pre-industrial periods. (The latter scenario can be considered an extreme variant.) Thus, if there is a sharp trend toward climate warming in the mid-21st century, we can expect the following: in winter, an air temperature increase of 2°C in northern Europe, 10°C in western Siberia, 10–14°C in eastern Siberia, and 10–12°C in northeastern Russia; in summer, an increase in all regions of 4–6°C; for the year, an increase of 2°C in the north part of western Europe and 2–6°C in the north part of eastern Europe, 8–10°C in the north part of western Siberia, 10–14°C in eastern Siberia, and 10–12°C in the eastern part of northern Russia.

On the whole, according to thermal conditions expected, climate warming in the 21st century would be favorable for vegetation. Natural zones would shift to the north by about 10° of latitude. At high latitudes, however, the precipitation amount might increase. In regions with very high humidity, the changes might lead to additional swampy areas. Thin permafrost and small islands of frozen rock would begin to thaw. The changes would also lead to undesirable cryogenic processes such as ice melting, downfall on the Earth's surface, collapse of slopes and shores, etc. International cooperation among scientists is needed for further research into climate change and its effects.

CONTAMINANTS AFFECTING THE ARCTIC CLIMATE, AND THE ROLE OF THE OCEANS

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We are increasingly impressed with the idea that the climate system must be treated globally, and, by the same token, most contaminants affecting the Arctic and its climate have global origins. This is manifestly true of carbon dioxide and its influence on surface temperature, through the greenhouse effect, and of chlorofluorocarbons that affect both the surface temperature and the stratospheric ozone layer. In both of these cases, the response of the Arctic is more dramatic than that in lower latitudes. Another type of contaminant that affects the arctic climate in the springtime is the light absorbing aerosols transported northward from industrial regions. Moreover, the Arctic includes several unique regional feedback mechanisms that can play a role in global climate change. Examples of these mechanisms are the effect that a global warming can have on the release of methane and carbon dioxide from the vast reservoir of organic material locked in the tundra and taiga (probably a positive feedback), and the effect of shrinking sea ice and snowcover on the heat balance of the globe (definitely a positive feedback). It has long been recognized that changes in ocean circulations, notably in the North Atlantic and Greenland Sea, can have a dominant effect on regional and global temperatures by temporarily transferring large quantities of heat from the surface to the deep ocean. There is now evidence that this surface cooling mechanism was probably active in the 1940 to 1975 period. All of these effects are poorly treated in current climate and ecosystem models, and introduce an element of uncertainty in predictions of global warming and the fate of contaminants in the Arctic.

MODELING OF CONTAMINANTS TRANSPORT, CLOUDINESS FORMATION, AND THEIR INTERACTION WITH RADIATION IN THE ARCTIC ATMOSPHERE

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The great uncertainty regarding the sensitivity of contemporary climatic models is related to the cloudiness description. The contaminants washout in the Arctic atmosphere and their fallout onto the underlying surface depends on processes of cloudiness formation. At present, observational satellite data (e.g., ISCCP, Nimbus-7, Meteor) and ground-based cloudiness data exhibit considerable disagreement in the polar regions. In particular, there is contradiction even in the signs of cloudiness changes from winter to summer. Large uncertainties in the polar region are associated also with aerosol (e.g., with Arctic haze), its evolution and influence on cloud formation, and radiative transfer. Two- and three-dimensional versions of mesoscale and regional models have been used to simulate cloudiness formation and the transport of contaminants in the Arctic atmosphere. The model includes a detailed description of microphysical processes. It is based on two kinetic equations for droplet and crystal size distribution functions along with a supersaturation equation. The explicit dependence of scattering and absorption coefficients on cloudiness and aerosol microstructure is taken into account. Processes in the model are essentially dependent on interactions with the underlying surface. In particular, we analyzed processes of cloudiness formation and contaminants transport under warm advection to the north in the Arctic over land, ocean, and ice.

GEOCHEMISTRY OF SNOW COVER OF THE NORTHEASTERN ASIAN ARCTIC

Vladimir N. Makarov, Geochemical Laboratory, Permafrost Institute, Siberian Branch, Russian Academy of Sciences, 26 Dzerzhinskogo Street, Apt. 43, Yakutsk, 677000, Russia

The snow cover geochemistry of arctic and subarctic parts of northeastern Asia was studied. A concept has been developed of fluxes in geochemical matter in the atmosphere during cold seasons. These fluxes constitute separate paths of matter exchanged in global processes between continental northeastern Asia and arctic seas and Pacific Ocean, land surface, and atmosphere. Results of geochemical studies on snow cover are presented as a series of maps that allow us to follow the character of aerosol contamination of tropospheric lower layers above the continent. The chemical composition of snow in major parts of the territory is influenced by several global factors, for example, climate continentality and salt transference from the core of the Asian continent. Marine effects are evident in coastal areas and chloride concentration increases significantly with distance from the coast. Anthropogenic contamination of snow cover is our focus because of certain features of economic development. In the chemical composition of snow cover in western Yakutia, regional anomaly is a major concern because of technogenic penetration of sulfur, nitrate, and heavy metals to the atmosphere from the Norilsk industrial region. An intensive pollution of snow cover negatively affects river water quality, since rivers are fed mainly by snow and subpermafrost water through taliks development areas, leading to contamination of soil and vegetation.

THE POSSIBLE EFFECT OF CLIMATIC WARMING ON ARCTIC PLANTS

E.A. Miroslavov and L.S. Bubolo, Komarov Institute of Botany, Russian Academy of Sciences, Professor Popov Str. 2, St. Petersburg, Russia

A comparative study of mesophyll cells was conducted using an electron microscope. The main object of study was a sampling of plants from the extreme north and the same or closely related species from the Leningrad district (*Astragalus alpinus, Poa pratensis, Cardamine pratensis, C. digitata, Ranunculus acris, R. sulphureus, Dryas punctata*). It was shown that the leaf chlorenchyma cells of all vestigated plants had great differences in structural peculiarities. Thus, the number of mitochondria per 100 mm^2 of median cell section in *A. alpinus* from Wrangel Island appeared to equal 4.0, while for *A. alpinus* from the Leningrad region, this number was equal to 2.4. The same data were obtained for other species. These data are in good agreement with the results of physiological studies. According to Ivanonva and Vaskovsky (1976), plants growing on Wrangel Island have a much higher respiration capacity than those growing in an average temperate climate. High respiration rates at low temperatures can have an advantage for early resumption of growth, but at high temperatures, they can lead to excessive consumption of carbohydrate reserves (Crawford and Palin, 1981). Thus the feature of arctic plants that provides for their growth in northern climates, namely highly developed hondreom, most likely will be a disadvantage if the climate becomes warmer.

Ivanova, T.I., and M.D. Vaskovsky. 1976. Bot. Zh. 61:324-331.
Crawford, R.M.M., and M.A. Palin. 1981. Flora 171:338-354.

TROPOSPHERIC OZONE MEASUREMENTS IN ICELAND AND THEIR RELATIONSHIP TO TRANSPORT FROM SOURCE REGIONS

Samuel J. Oltmans[1], J. Prospero[2], B. Doddridge[3], H. Hjartarson[4], and E. Sigurdsson[4]

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[4] Icelandic Meteorological Office, Reykjavik, Iceland.

One year of continuous ozone measurements from Reykjavik and Westman Islands, Iceland, are compared in their diurnal, synoptic, and seasonal variability. Although the Reykjavik location is heavily influenced by pollutant emissions, primarily from automobiles, the underlying synoptic scale and seasonal variations are quite similar to those found at Westman Islands, a remote, background site. This suggests that large-scale transport events are responsible for much of the day-to-day and seasonal variability. Both sites show a maximum ozone concentration in the spring and minimum in the summer. The ozone behavior during two seasons at Westman Islands is investigated in relationship to particulate nitrate and carbon monoxide as tracers of continental emissions. Several detailed vertical profiles of ozone in the troposphere over Iceland in August are compared with the surface based measurements. At the clean Westman Island site, there is no discernible diurnal variation, while at Reykjavik, there is a strong variation, with the highest amounts early in the morning and lowest values during the day. This variation appears to be related to daily automobile activity and probably results from titration by nitric oxide.

BLACK CARBON (SOOT) AEROSOL IN THE ARCTIC ATMOSPHERE

Rudolf F. Pueschel and D.F. Blake, NASA Ames Research Center, Moffett Field, California 94035-1000, USA

As determined by impactor samplers flown on a DC-8 aircraft, black carbon aerosol (BCA) mass loadings in the arctic stratosphere amount to 0.22 ng/m^3, or 42 ppmm of the total aerosol after the 1991 Pinatubo volcanic eruption. In the arctic troposphere, the BCA fraction increases to 0.2% of a total aerosol loading of 1.3 μg/m^3. The low concentration in the stratosphere is commensurate with present commercial air traffic fuel consumption, if one assumes an emission factor of BCA of 10^{-4}, 10% of commercial air traffic taking place in polar routes, and average BCA residence time in the stratosphere of about one year. The much higher concentration in the troposphere is most likely due to industrial sources in Europe and/or North America. We are investigating signatures, such as trace elements and air mass trajectories, to identify the source of BCA observed at any given time. Taking BCA into account, the atmospheric aerosol single scatter albedo is $\approx$0.998 in the troposphere, and larger by 0.2% in the stratosphere.

INCREASE IN ATMOSPHERIC METHANE AND HYDROGEN PEROXIDE

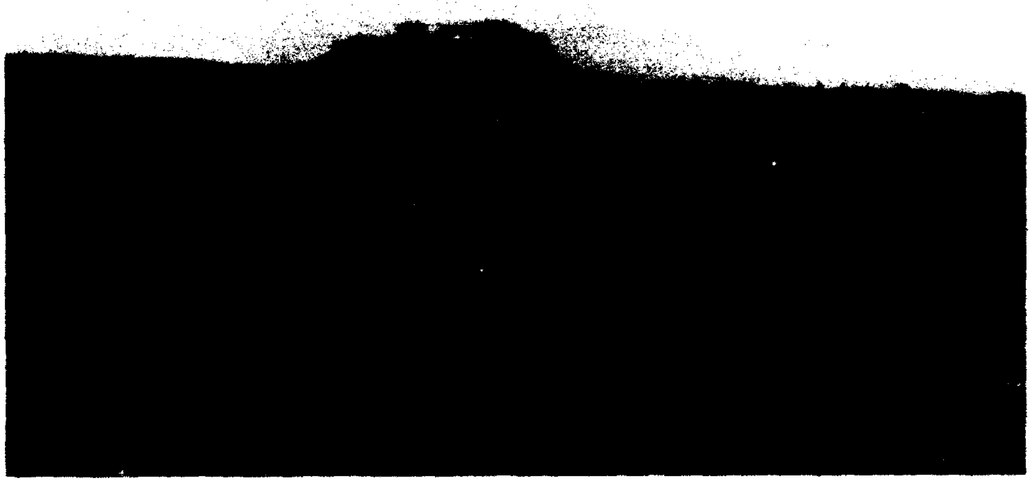
Igor P. Semiletov, Pacific Oceanological Institute, 44 Baltivskaya St., Vladivostok, Russia

The methane record in Greenland and Antarctic ice cores shows a 30% increase in air content from 1951 to 1985 and a 100% increase over the past 200 years. What is the cause of the CH_4 buildup? We will consider only relations with main tracing compounds. It is known that CH_4 is removed from the atmosphere principally by reacting with OH radicals. Consequently, decreased levels of OH may have contributed to the CH_4 increase. Joint analysis of the main photochemical reactions, along with paleorecords of atmospheric pollutants in polar ice cores, shows the following: In the atmosphere, CH_4 cycling is the source of HO_2 radicals and the sink for OH radicals. Likewise, hydrogen peroxide, H_2O_2, acts as a reservoir species of OH radicals. The H_2O_2 record from Greenland ice cores shows a 50% increase over the past 200 years, with ~30% increase occurring in the 1951–1985 years. Consequently, we may assume that atmospheric H_2O_2 prevents the oxidation of CH_4 by OH radicals. We should also note that in the ice cores, H_2O_2 depletions are associated with volcanic deposits, because in the aqueous phase H_2O_2 plays a key role in the oxidation of SO_2 to H_2SO_4 in clouds. Thus, positive H_2O_2 oscillations are related to amplification of the greenhouse effect by CH_4 increase. Otherwise, the negative oscillations may indicate the increase in concentration of the main aerosol, H_2SO_4. In the Arctic atmosphere, where the CH_4 global maxima is obtained, we may also find coincident H_2O_2 maxima.

COSMIC RAY RADIATION AS A FACTOR FOR ATMOSPHERIC CO_2 DECREASE

Igor P. Semiletov, Y.M. Kharlamov, and A.Y. Nikitin, Pacific Oceanological Institute, 44 Baltiyskaya Street, Vladivostok 690041, Russia

Recent data show that terrestrial arctic ecosystems provide significant CO_2 emission to the atmosphere. Additional sinks for the main greenhouse pollutant, atmospheric CO_2, are being sought. Many meteorologists suppose that vertical distribution of CO_2 (volume mixing ratio) is homogenic to an altitude of 110 km. However, measurements of the abundance of CO_2 between ground and 35 km shows the CO_2 volume mixing ratio decreasing from tropopause level to a mid-stratospheric level by 7 ppmv—this decrease taking place almost entirely within the 16–22 km altitude range. Likewise, this altitude layer coincides with maximal fluxes of primary/secondary high-energy particles produced by the interaction of galactic cosmic ray radiation with the atmosphere. Consequently, we assume that CO_2 stratospheric decrease is determined by spallation reactions and interactions with air nuclei/molecules. The process of cascade interactions between primary/secondary cosmic ray radiation and the atmosphere was modelled. It was also shown that the paleo-correlation coefficient between the ^{10}Be cosmogenic record and atmospheric CO_2 content in the Vostok ice core is about –0.68. Due to minimal geomagnetism in polar regions, the foregoing effect might be most significant in the Arctic and Antarctic.



Mt. McKinley in the twilight sky, taken from Fairbanks, Alaska, just below the Arctic Circle.

HIGH-LATITUDE BOREAL FOREST ECOSYSTEM CONTAMINANTS: MONITORING AND RESEARCH IN LANDSCAPE-SCALE CATCHMENTS

Charles W. Slaughter, Aquatic/Land Interactions Research Program, Institute of Northern Forestry, USDA Forest Service, 308 Tanana Drive, Fairbanks, Alaska 99775, USA

Assessment of contaminants and their effects in high-latitude ecosystems presupposes knowledge of baselines—the precontamination state. Baseline conditions and change over time can appropriately be addressed at the landscape level, examining mass, nutrient and contaminant inputs, processing, and outputs in hydrologically defined landscape units (watersheds). While conceptually attractive, this is not easily achieved in practice. One example is underway in a hydrologically bounded 104-km^2 taiga (northern boreal forest) research watershed at 65°N in central Alaska. Numerous discrete, first-order subunits (catchments) vary in elevation and dominant aspect, forest species composition, and proportion of permafrost (perennially frozen ground). Several are reserved for experimental manipulation by selected resource management practices. Hydrologic inputs are monitored through a precipitation and snowfall network. Precipitation chemistry and "contaminants" are monitored at a single location, a National Atmospheric Deposition Program (NADP) station sited in a central valley. Output (streamflow) is monitored at the drainage outlets of four first-order (headwaters) catchments; the composite flow of multiple catchments is measured at downstream locations. Precipitation constituents monitored include Ca, Mg, K, Na, NH_4, NO_3, Cl, SO_4, PO_4, pH, and conductivity. Stream water is sampled for determination of the same species and for suspended sediment. Complementary studies of stream system biological productivity are conducted in selected reaches of the same streams. Terrestrial vegetation is monitored in permanently reserved 25-ha plots established in dominant vegetation/landform types: alpine/subalpine, deciduous (permafrost-free) forest, coniferous (permafrost-dominated) woodland, and riparian (permafrost-underlain) woodland/tall shrub. Results are compared with limited (1985, 1987) data acquired in a more remote, pristine boreal forest ecosystem in the Noatak River watershed in extreme northwest Alaska. this landscape approach to ecosystem status and contamination constitutes a valuable tool in understanding current and future conditions of subarctic boreal forest ecosystems.

THE ATMOSPHERIC RADIATION MEASUREMENT (ARM) PROGRAM: ARM'S WINDOW ON THE ARCTIC

Knut Stamnes[1], B. Zak[2], and G. Shaw[1]

[1] Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska 99775-0800, USA.
[2] Sandia National Laboratories, Albuquerque, New Mexico 87185-5800, USA.

A "blue ribbon" committee established by the United States National Academy of Sciences has stated that uncertainties associated with cloud behavior constitute the major obstacle to progress in climate modelling and prediction. ARM is a 10-year climate research program aimed at unravelling the role of clouds in the climate system. As such, it constitutes a major portion of DOE's contribution to global change studies. The focus of this new ARM program is to improve our understanding of the role of clouds in the climate system by studying their "life cycle," as well as their effects on the radiative heat balance. The plan is to establish five major research sites around the globe; one of them will be on the north slope of Alaska. Cloud behavior in the Arctic is expected to be significantly affected by pollution "episodes," such as the arctic haze phenomenon, which by itself perturbs the heat balance of the Arctic. Our aim is to design a research program in connection with this site that will help answer questions such as, "What is the relationship between arctic clouds and human-made pollution transported to the north from lower latitudes?" and "What is the interaction between arctic clouds and sea ice growth and decay?" A research plan and strategy designed to address these and related questions will be discussed.

CARBON MONOXIDE AND TOTAL OZONE IN THE ARCTIC AND ANTARCTIC: SEASONAL VARIATIONS, LONG-TERM TRENDS, AND RELATIONSHIPS

Leonid N. Yurganov, Arctic and Antarctic Research Institute, 38 Bering Street, St. Petersburg 199397, Russia

Total column abundances of carbon monoxide and ozone have been measured for some time at the Mirny Observatory in the Antarctic. During every spring season, CO was found to diminish, but the interannual variability of absolute abundances of both measured components was considerable. We measured the same type of CO variations (with a base shift of 0.5 year and two-and-one-half times higher values) in the Arctic (Severnaya Zemlya, Wrangel Island). Due to the short residence time of this gas in the atmosphere (a few months), CO variations in both polar regions of the planet have to be considered as independent, evidently caused by tropospheric OH changes. In turn, OH concentration depends on UV radiation controlled mainly by ozone. Thus, it is reasonable to expect a correlation between CO and ozone changes. This correlation has been estimated for interannual variations of these gases in the Antarctic. Bearing in mind the possibility of ozone depletion in the Arctic (like that in the Antarctic), we could estimate the influence of this depletion on CO, CH_4, and other gases under the control of tropospheric hydroxyl. This depletion would be qualitative and we would observe upward trends of CO, CH_4, methyl chloroform, many hydrocarbons (e.g., ethane), and many other climatically important species.

THE CARBON BUDGET OF NORTHERN ECOSYSTEMS AND ITS RESPONSE TO ATMOSPHERIC POLLUTION

Sergei Zimov[1], S.P. Daviodov[1], Y.V. Voropaev[1], S.F. Prosiannikov[1], I.P. Semiletov[2], M.C. Chapin[3], and F.S. Chapin, III[3]

[1] Northeast Scientific Station, Pacific Institute for Geography, Far East Branch, Russian Academy of Sciences, Cherski, Republic of Sakha, Yakutia, Russia.
[2] Pacific Oceanographic Institute, Far East Branch, Russian Academy of Sciences, Vladivostok, Russia.
[3] Department of Integrative biology, University of California, Berkeley, California, USA.

The maximum concentration of atmospheric CO_2 occurs at 70°N latitude, suggesting that northern ecosystems are currently large sources of CO_2. Mosses and lichens, which determine the thermal insulation of the soil surface, are highly sensitive to atmospheric pollution. We suggest that their degradation has increased the depth of melting of soils and the release of carbon, leading to the observed soil efflux from northern ecosystems. Three years of year-round CO_2 flux measurements from the Kolyma lowlands (69°N) have demonstrated large fluxes of CO_2 from the land to the atmosphere, particularly during winter (September–December and April–May). These are the first measurements of winter CO_2 fluxes from northern ecosystems; therefore, they have not been included in previous estimates of northern CO_2 flux and increase the importance of the North as a CO_2 source to the atmosphere. Using data on precipitation and runoff for the Kolyma watershed, we estimated evapotranspiration for the region for the past 50 years. Because evapotranspiration is strongly correlated with photosynthesis, we can use these data as a proxy for the historical record of CO_2 flux. These data show that ecosystems of the Kolyma accumulated carbon until 1970 and have since been releasing carbon. These data are consistent with our chamber flux measurements and with the high atmospheric concentration of CO_2 at high latitudes.

THE DISTRIBUTION OF GREENHOUSE GAS CONCENTRATIONS IN THE ARCTIC REGION EVALUATED FROM FIELD MEASUREMENTS AND 2-D PHOTOCHEMICAL MODEL CALCULATIONS

Serguey Zvenigorodski and Nikita Pugatchev, Environmental Branch of the Russian Academy of Sciences, Box 60, St. Petersburg 195112, Russia

Some results of numerical calculation of greenhouse gas concentrations using a 2-D photochemical model, as well as results of field measurements are presented. The model concentration of CH_4 was compared with experimental measurements, and lack of agreement in these data is under discussion. The main reason for this discrepancy between experimental and theoretical data may be related to the existence of currently unestimated anthropogenic sources of methane caused by leakages of CH_4 from tubes and pumping stations in the arctic and subarctic regions of Russia.

F. INFORMATION GAPS AND RESEARCH NEEDS

Organizer: Dixon Landers

Purpose: The final session of the Symposium will be a panel discussion designed to summarize and synthesize the scientific information presented at the Symposium and to identify the important gaps in our knowledge regarding the nature and effects of contaminants in arctic ecosystems. The information gaps will be identified from both scientific and policy perspectives with the intention of assisting circumarctic countries in focusing future research on the questions of greatest importance.

ORAL PRESENTATIONS

1:30 - 3:30	Dixon Landers
	Heikki Sisula
	Lars-Erik Liljelund
	Theo Colborn
	Garth Bangay

UTILIZING THE INTERNATIONAL ARCTIC BUOY PROGRAM FOR ENVIRONMENTAL MONITORING IN THE ARCTIC BASIN

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One of the major gaps in evaluating the current state of the environment in the Arctic and in monitoring its future development is the lack of an appropriate assessment of environmental parameters in the Arctic Basin. There is a clear need particularly for estimating the magnitude and spatial distributions of heavy metal and organochlorine (PCBs, DDTs) deposition in arctic waters. Information about these pollutants is currently available only through sporadic investigations on tissue materials from fish or other marine organisms. However, lipid-soluble contaminants should receive top priority, since they may have detrimental long-term effects on the physiology of top predators, including humans. The International Arctic Buoy Program (IABP) consists of a network of up to 20 automatic buoys, which are drifting with the sea ice in the Arctic Basin. They transmit valuable information on surface air temperature, air pressure, and sea ice drift on a synoptic basis through the ARGOS satellite network. This paper discusses possible ways of utilizing the IABP to also measure atmospheric key pollutants on a weekly basis. We envision the deployment of so-called TENAX tubes in sealable containers, which would be exposed, one at a time, to the ambient atmosphere. After recovery of the containers, the tubes could be analyzed in a land-based laboratory, giving concentrations of certain pollutants at a specific position and a specific point in time. This then would yield important information on the spatial and temporal distribution of a selected number of contaminants over the Arctic Ocean. The paper discusses the major technical concepts for using the IABP for this purpose, the general feasibility of such a project, and its integration into the Arctic Monitoring and Assessment Programme (AMAP).

INTERNATIONAL INSTITUTIONAL MECHANISMS FOR ADDRESSING ARCTIC POLLUTION: CAN PROBLEMS BE TRANSFORMED INTO SOLUTIONS?

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This paper discusses the issue of arctic pollution in the context of trends in world economic growth, globalization of economic activity, international trade, and related institutional arrangements (such as trade and environmental agreements). The importance of tracing the sources of particular contaminants is stressed; this is a first step towards internationalizing the environmental costs of production, and is also an important political key in efforts to control emissions. Trade and investment agreements commonly discuss rules for cross-border flows of goods, services, personnel, and investment capital, as well as matters specific to particular economic sectors. Cross-border flows of pollutants and other "bads" also merit detailed sectoral attention. This linkage would make explicit the connections between production and pollution (making possible the "polluter pays" approach), and would also widen the scope for redistribution of economic resources to equilibrate the situation (via trade and investment measures, among others) where flows of goods would relate directly to flows of "bads." The paper concludes with an examination of the outlook for addressing arctic pollution via international environmental agreements (along the lines of the Basel Convention, the Montreal Protocol, Cites, etc.), existing and future trade agreements (such as GATT, NAFTA, and the European Energy Charter), or new institutional approaches.

CHEMICAL COMPOSITION OF SNOW FROM COASTAL SITES OF RIGA GULF, LATVIA

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Concentrations of the contaminants in the new fallen snow samples collected from 49 sampling sites near the sea coast of Riga Gulf and in the adjacent forest areas were determined to evaluate the level of air pollution in winter and its load to the Baltic Sea. Standard colorimetric analytical methods were used for sulfate, phosphate, chloride, nitrate, bicarbonate, and ammonium; atomic absorption spectroscopy and potentiometric stripping were used to determine metals (Na, K, Ca, Mg, Fe, Ni, Co, Cr, Mn, Zn, Cd, Pb, and Cu). The highest concentrations of these metals existed in the soluble fractions of the snow. Significant influence of sea water spray on the snow composition was observed for the samples collected from the sea shore. An attempt was made to correlate regional differences in the snow composition with the meteorological conditions in the atmosphere during snow fall, and the potential influence of large industrial centers. The comparison of snow samples taken from the sites where the influences of anthropological factors were minimal and heavily contaminated snow samples from the city of Ventspils is given. The results of present snow sample analyses (1993) and previous investigations during the winter of 1986 and 1987 are discussed.

THEORETICAL ASPECTS OF THE COMPOSITION OF TECHNICAL TOXAPHENE AND ENVIRONMENTAL RESIDUES, AND THEIR PROOF BY CHROMATOGRAPHIC AND SPECTROSCOPIC METHODS

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Toxaphene, a complex mixture of polychlorinated camphenes with a broad spectrum of pesticidal activity, is one of the major contaminants of chlorinated hydrocarbons in arctic regions. However, atmospheric long-range transport and biodegradation in higher organisms lead to a changed composition of toxaphene residues in the environment, compared to the technical toxaphene mixture. Due to the lack of commercially available toxaphene single standards, the quantitative determination of toxaphene residues by gc/ms and gc/ecd is still a problem.

Results from chromatographic (gc multidimensional gc, hplc) and spectroscopic (nmr, ms/ms, ms) methods will be compared to theoretical calculations, giving a deeper insight into the composition of toxaphene standard mixtures and residues in the environment, as well as the stability and stereochemistry of single toxaphene components. Based on these data, the analytical and toxicological behavior of toxaphene residues will be discussed.

ECOLOGICAL DISASTERS AND DECISION SUPPORT SYSTEM

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Giving an account of ecological conditions at production installations is an important part of the work of managers (decision makers), especially in fields such as agriculture, marine fishery, and aviation. In creating this system, we used the "shell" of the expert system, SPRINT, originally developed in Russia. SPRINT enables the simultaneous creation of about 250 diversely oriented subsystems. The DSS, which supports ecology, the merchant marine, and other studies or organizations, provides examples. The major principle in developing a DSS is to combine processes of creating message (effect) bases, bases of recommendations, and knowledge as individual process stages that provide for very rapid debugging of the knowledge base. Associations between the values of the environmental parameters and the messages are established in the form of logical conditions "if..., then...". There is a specific list of messages for each current and forecast climatic value of the environmental parameters. The set of messages is also different for different management levels. The list of messages also depends on the type of measures (tactical, strategic, current) to be taken, the season of the year, and the objective. A specific recommendation corresponds to each message. As the system develops along with purely informational support, decision makers will acquire possibilities for optimizing certain characteristics of the effect on installations and for computing economic characteristics.

AUTHOR INDEX

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